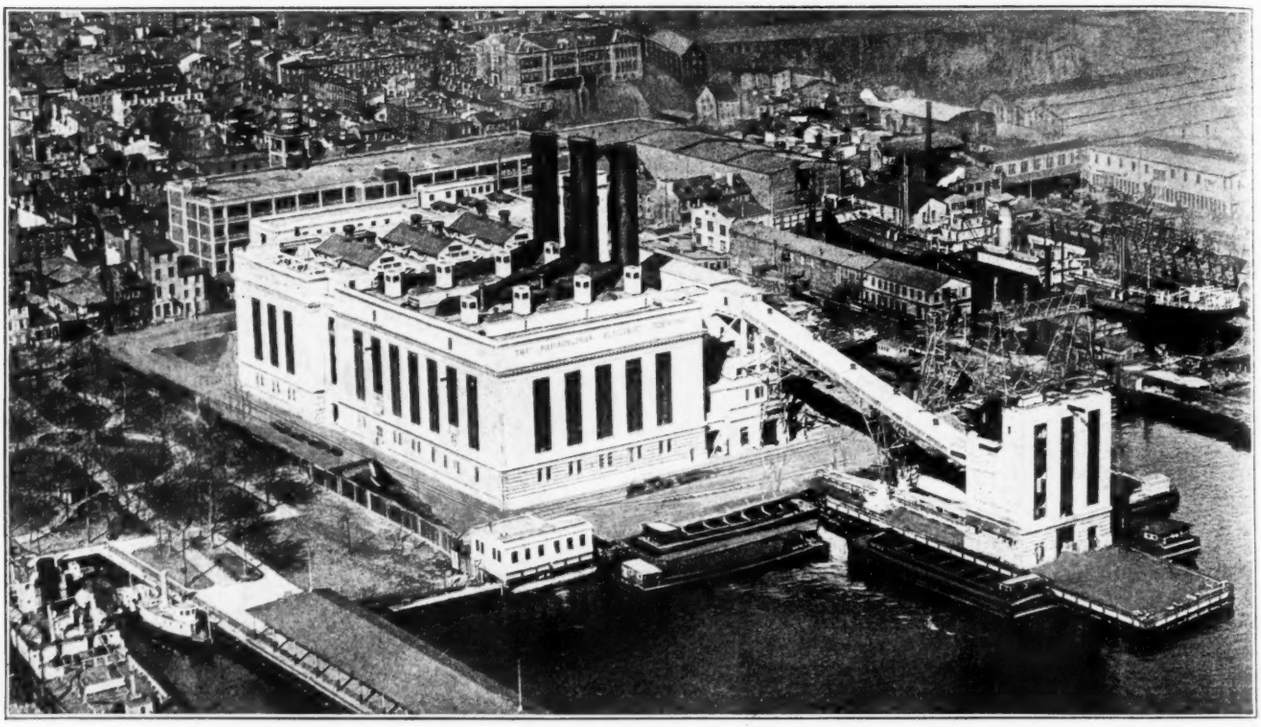
POWER

Volume 53 New York, May 24, 1921 Number 21

" HARNESSING THE FALLS "



Delaware Power Station—The Philadelphia Electric Company

Station Designed for 180,000 Kw., in Six 30,000-Kw. Units—60,000 Kw. Installed —Building Constructed of Reinforced Concrete—Boilers Set Exceptionally High —Ratio Furnace Volume to Heating Surface 0.48 cu. ft. to 1 sq. ft.— Heat-balance and Feed-water System of Special Interest

PHILADELPHIA, known as the "workshop of the world," is exceptional not only because of the number of manufacturing establishments, but also on account of the wide diversity in the character of these industries.

This city, with two million inhabitants and over fifteen thousand manufacturing companies, is supplied with electrical energy from the power system of the Philadelphia Electric Co., which in 1920 reached a total capacity of approximately 250,000 kw. During the last year the peak load reached 203,625 kw. and the total number of kilowatt-hours generated was 910,065,068.

This load is made up of the commercial light and power business, a large percentage of the street-railway load of the Philadelphia Rapid Transit Co. and energy for the operation of the electrified zone of the Pennsylvania Railroad System running out of Philadelphia.

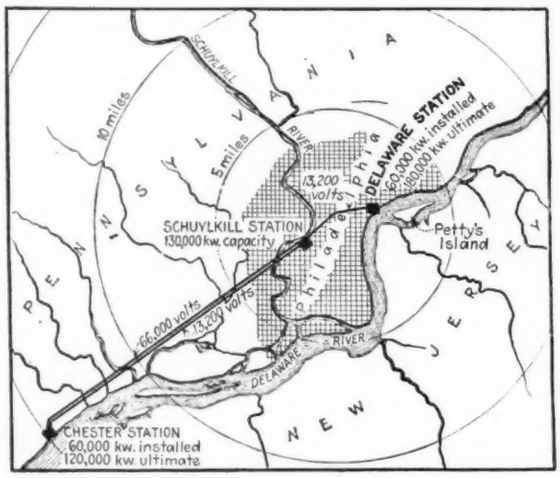


FIG. 1. MAP SHOWING LOCATION OF MAIN STATIONS OF THE PHILADELPHIA ELECTRIC COMPANY

Power is supplied from three main generating stations—the Schuylkill Station on the Schuylkill River, and the Chester and Delaware Stations, both located on the Delaware River.

In 1915 Schuylkill Station was developed to its maximum capacity of 130,000 kw., therefore other provisions had to be made for increasing the system capacity to meet demands imposed by a rapidly growing load. At that time the industrial district around Chester, which was served by a duplicate 66,000-volt line from Schuylkill and from a small station at Chester, had increased to such proportions and gave promise to continue to increase to such an extent as to warrant a new station in this locality. Furthermore, the plant at Chester was fast becoming antiquated except as a stand-by station. To meet this demand the design of a new station was laid down to have an ultimate capacity of 120,000 kw. in

four 30,000-kw. units—two of which have been installed. During the war Chester was the center of some of the most important war industries—shipyards, machinery-manufacturing establishments and munition factories. The success of these depended in large part upon Chester Station for power. Power was also furnished from Chester to help out the load being supplied from Schuylkill Station, where a serious shortage existed.

Before Chester was completed, further increase in station capacity was necessary to take care of the load in the Philadelphia district, especially in the section known as Kensington, which is one of the largest textile manufacturing centers in this country. In addition to this class of manufacturing there are many other large industries. From a study of the load it was evident that the demand for power in this district would continue to increase for many years to come, and this made the site of the present Delaware Station one of the most logical locations for the new plant. Furthermore, it was within transmission distance, at generator voltage, of the district served from Schuylkill Station, and the company had succeeded in securing a 5-acre tract of land, suitable for a station site, which had been an old shipyard on the Delaware River. This site was also only 3,000 ft. away from the company's main coal-storage yard on Petty's Island (see map, Fig. 1).

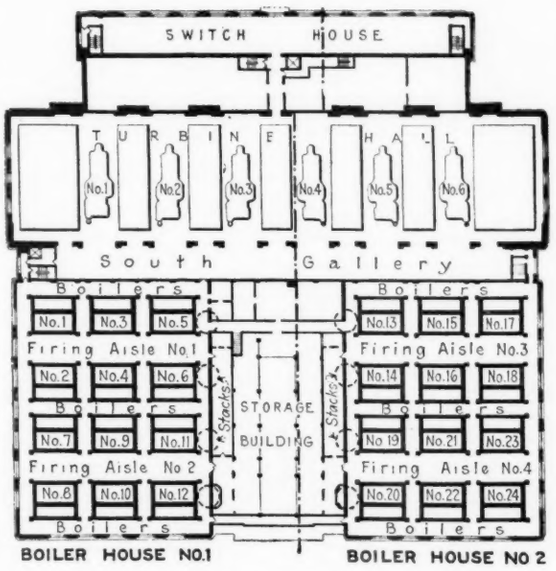


FIG. 2. LAYOUT OF DELAWARE STATION

Delaware Station has been designed for an ultimate capacity of 180,000 kw. divided into six 30,000-kw. units, two of which have been installed to date. Construction was begun on the station by Stone & Webster, Inc., in Sept., 1919, and in Oct., 1920, 13 months later, the first unit was put into service. The design of the station, which was made by the Philadelphia Electric Co. engineers and John C. Windrim, architect for the building, was laid down during the war, when it was practically impossible to obtain structural steel; therefore it was decided to construct the building of reinforced concrete. The only exception to this is the roof trusses of the turbine hall, which are of structural steel fireproofed with concrete, and the skeleton of the foundations for the turbines, which are also of structural steel and concrete. It is believed that this is one of the largest reinforced-concrete buildings ever constructed for a power plant.

As shown in Fig. 2, the plant comprises five buildings: Switchhouse, turbine hall, boiler house No. 1, storage building and boiler house No. 2. The part of

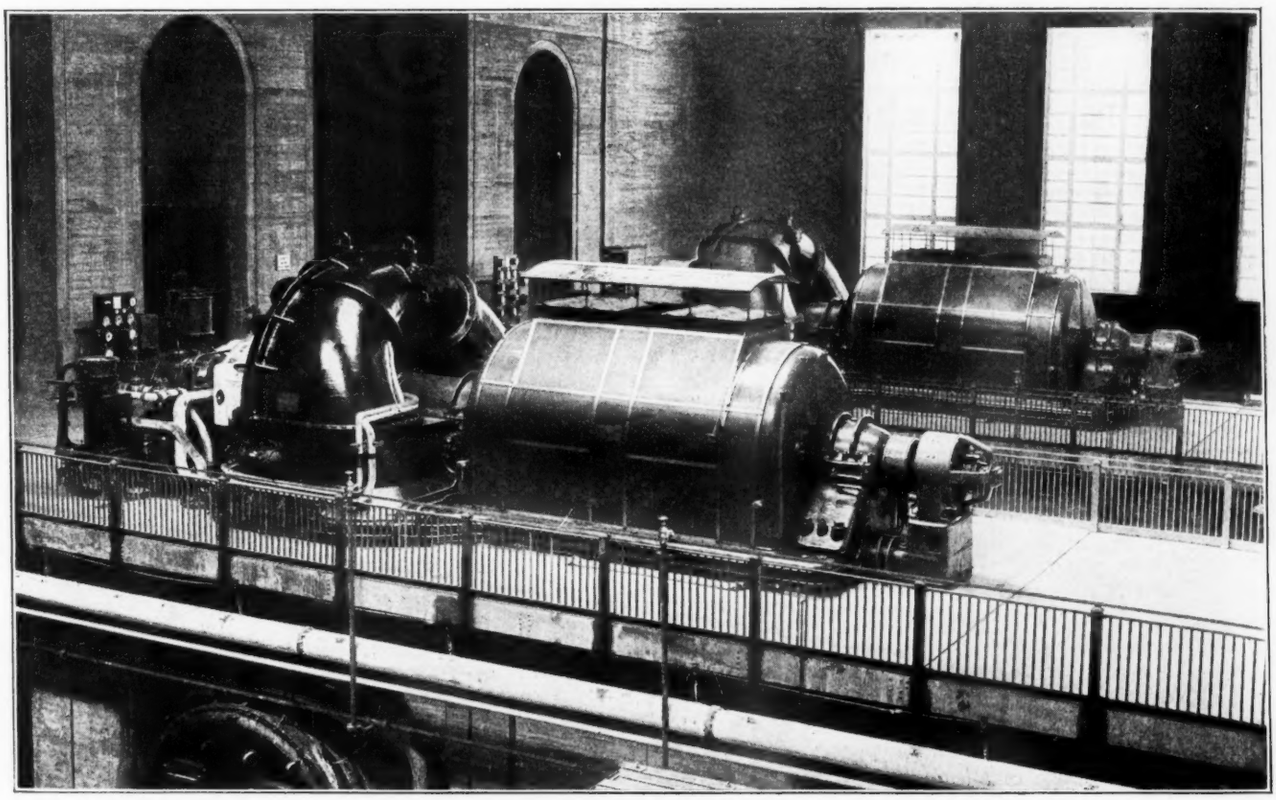


FIG. 3. VIEW OF TURBINE HALL; TWO 30,000-KW. UNITS INSTALLED

the building completed at present is that to the left of the dotted line on the figure and provides space for three turbines and 12 boilers; that is, 50 per cent of the ultimate capacity of the station. Over the storage building are the main coal conveyors, both of which are now installed.

Foundation for the present building was obtained by driving 28 caissons 15 to 18 ft. in diameter to bedrock at a maximum depth of 50 ft. and filling these with concrete. These caissons are at points of greatest load and are tied together with reinforced-concrete girders, and this laid over with a reinforced concrete slab.

The plot on which the building is located is only 5 acres in area, 3½ acres of which will be covered by the building when the plant is completed. It was desirable to locate on this property standard-gage railway tracks for the handling of machinery and also to obtain an emergency coal supply by rail. This practically made it necessary to place the coal tower on a pier extending cut into the river to the harbor line, which was done.

From the foregoing it is evident that the ultimate capacity of the station is limited by the size of the property available, and this placed the figure at 180,000 kw. After deciding the maximum capacity of the plant, the choice of the size of the main unit must be determined. With the Philadelphia Electric Co., units of 30,000 kw. capacity have been practically adopted as a standard. It is considered that such units are practically as high in efficiency as machines of larger size, and they can be constructed in a single cylinder to give maximum reliability. On a system the size of the Philadelphia Electric Co.'s, one machine may be put out of service without seriously interfering with the system's operation, and in normal operation the switching on and off of a single unit does not materially affect the efficiency of the system as a whole.

Main Turbo-Generator Units

Each of the main units, Fig. 3, consists of a 30,000-kw. General Electric single-cylinder turbo-generator operating at 1,800 r.p.m. The turbines have 17 stages and exhaust into Westinghouse surface condensers having 50,000 sq.ft. of cooling surface in a single shell, made up of 9,094 one-inch No. 18 B.w.g. Admiralty-Mixture tubes, 21 ft. 3 in. long. Turbine and condenser are bolted rigidly together, the latter resting on double-coil springs. A structural-steel and concrete foundation is provided for each turbine. These foundations are independent of the building structure, so that vibration from the machines will not be transmitted to the building.

With steam at 235 lb. gage at the throttle and 175 deg. superheat, giving a total temperature of 576 deg. and expanding down to a condenser pressure of 1 in. of mercury, the turbines will produce a kilowatt-hour on

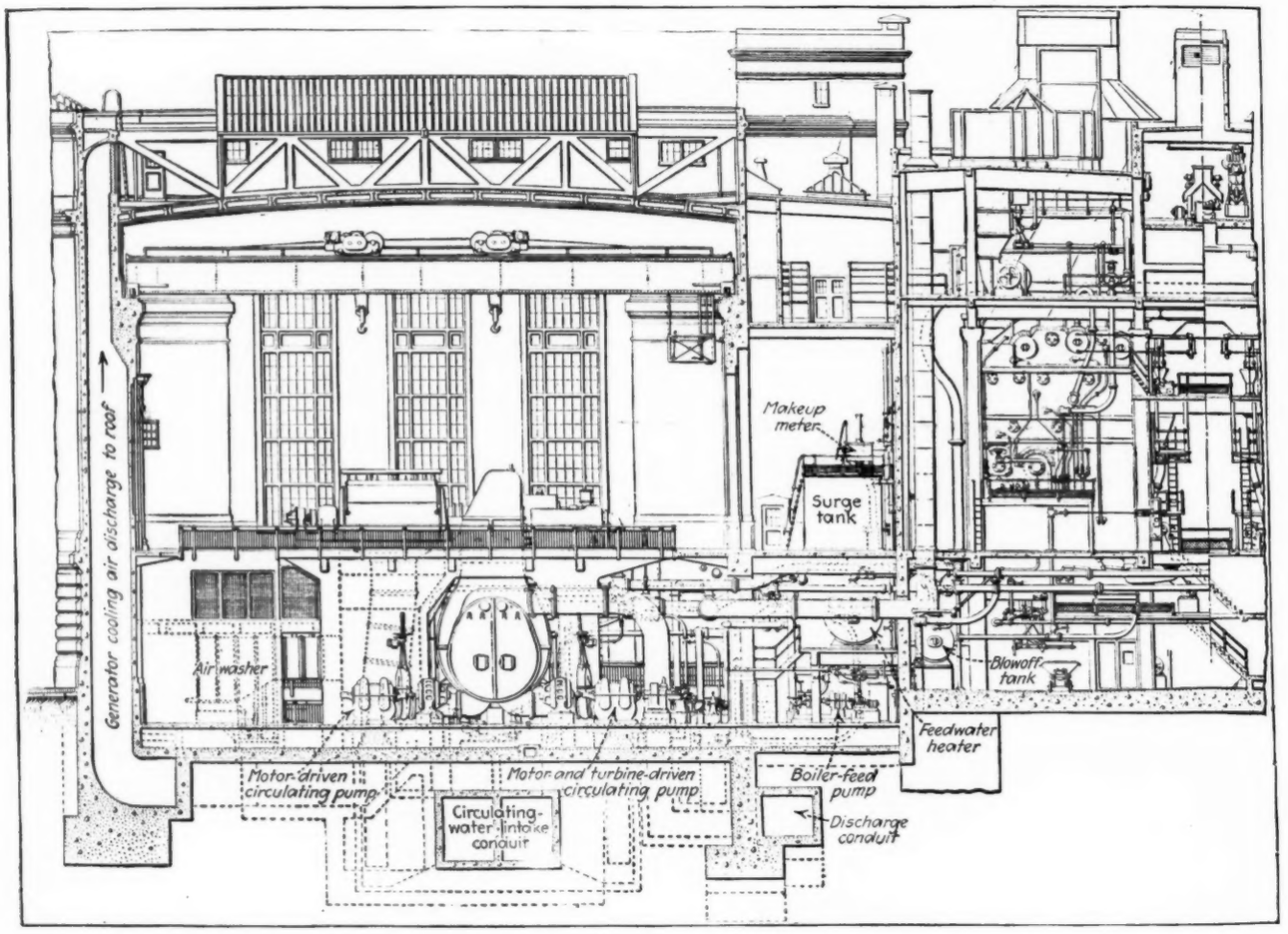


FIG. 4. CROSS-SECTION THROUGH TURBINE HALL AND PART OF BOILER ROOM

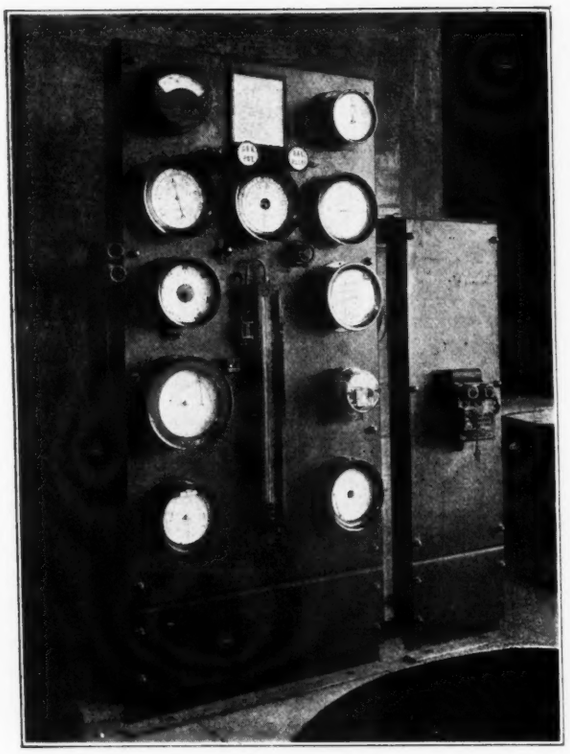


FIG. 5. TURBINE INSTRUMENT BOARD

a steam consumption of 10.8 lb. when developing 22,000-kw., which is the most efficient load.

Near each main unit is an instrument board on which are mounted the necessary gages and instruments, both steam and electrical and signal devices for the operation of the machine. The general arrangement of this board and instruments is shown in Fig. 5.

In each main steam connection between the turbines and boilers, just inside the boiler-room wall, there is installed an electrically operated quick-closing throttle-type valve. These valves can be operated either from the boiler room or from the turbine-operating board, so that the steam may be shut off quickly in case of failure of a steam line inside the turbine hall.

Each condenser has two circulating pumps of 37,500 gal. per min. capacity. One is driven by a 430-hp., 2,400-volt induction motor, and the other has a duplex drive, being equipped with both a steam turbine and a 430-hp. motor, either of which can drive the pump when the latter is delivering its full rated capacity, the load carried by either driving unit being fixed by the steam required for the heat balance. As shown in Fig. 7, the circulating pumps have independent intake conduits, thus making the circulating-water system in duplicate throughout, with the exception of the discharge conduit, which is designed to serve three units. When the station is completed, a second discharge conduit will serve three other units and the present intake conduits will be extended throughout the full length of the station, so that any one of the six units may take its circulating water from either one of the intake tunnels. Making the circulating-water system in duplicate allows one half of the system to be cut out of service for repair to screens, etc., and the plant operated on the other half. On each condenser there are also two condensate pumps of 1,500 gal. per min. capacity, one driven by a 125-hp. 240-volt induction motor and the other by a turbine. Two air-removal pumps are furnished, one driven by a 95-hp. induction motor and the other by a turbine.

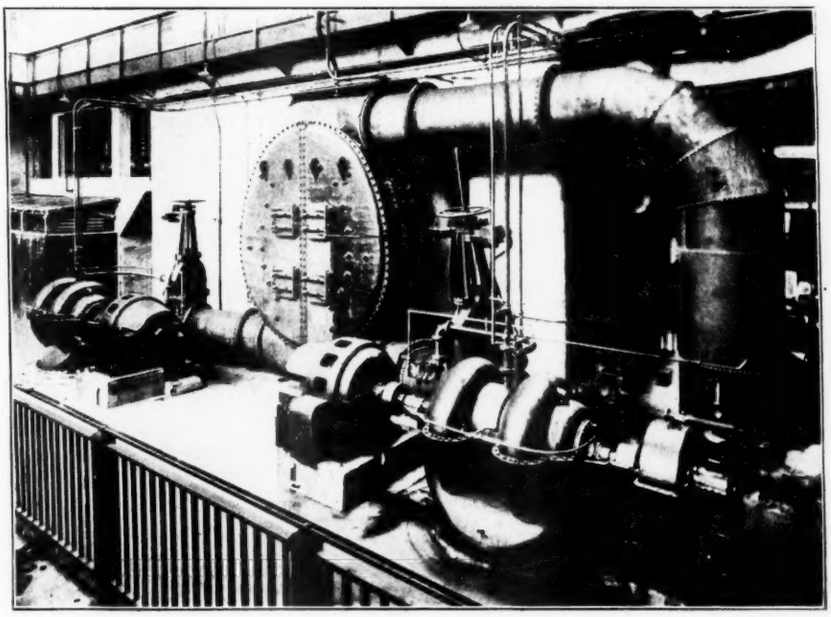


FIG. 6. EACH CONDENSER HAS TWO CIRCULATING PUMPS

Heat Balance

At the time the auxiliary system was laid out for this plant, it was found desirable to design the system so that boiler feed-water temperatures could be maintained at about 210 deg. F. to secure protection against pitting of economizer tubes and piping. At that time the only practical way of removing air from the feed water was by raising its temperature in the heater to the boiling point, but investigations were then under way which, if successful, would make it possible to operate the boiler-feed system at lower temperatures with a resulting increase in boiler efficiency. For this reason considerable thought was given to the method of obtaining a heat balance which would allow of reliable and economical operation with feed water at any point in the temperature range between 140 deg. F. and 212 deg. F.

Keeping in mind the reliability and operating economies obtainable, as well as the item of investment, it was decided to install the condenser auxiliaries in duplicate in all cases and drive them as described in the foregoing. The base steam requirements for any desired boiler feed-water temperature can therefore be secured through use of the steam-driven boiler-feed pumps in conjunction with the necessary number of steam-driven condenser auxiliaries. The variations necessary for maintaining a constant temperature are secured through the duplex-driven circulating pumps. As one pump is all that is required to supply circu-

lating water to each condenser, during the winter months the duplex-driven circulating pump is the only one used, consequently the motor-driven pump is operated during the summer months only.

An additional advantage obtained with the use of the duplex drive on the circulating pumps is the fact that in case of an interruption to the electrical system, the circulating pump would still remain in service. The entire regulation of the feed-water temperature with this arrangement is entirely under control of the man responsible for the operation of this section of the plant apparatus. A bleeder connection has been provided at

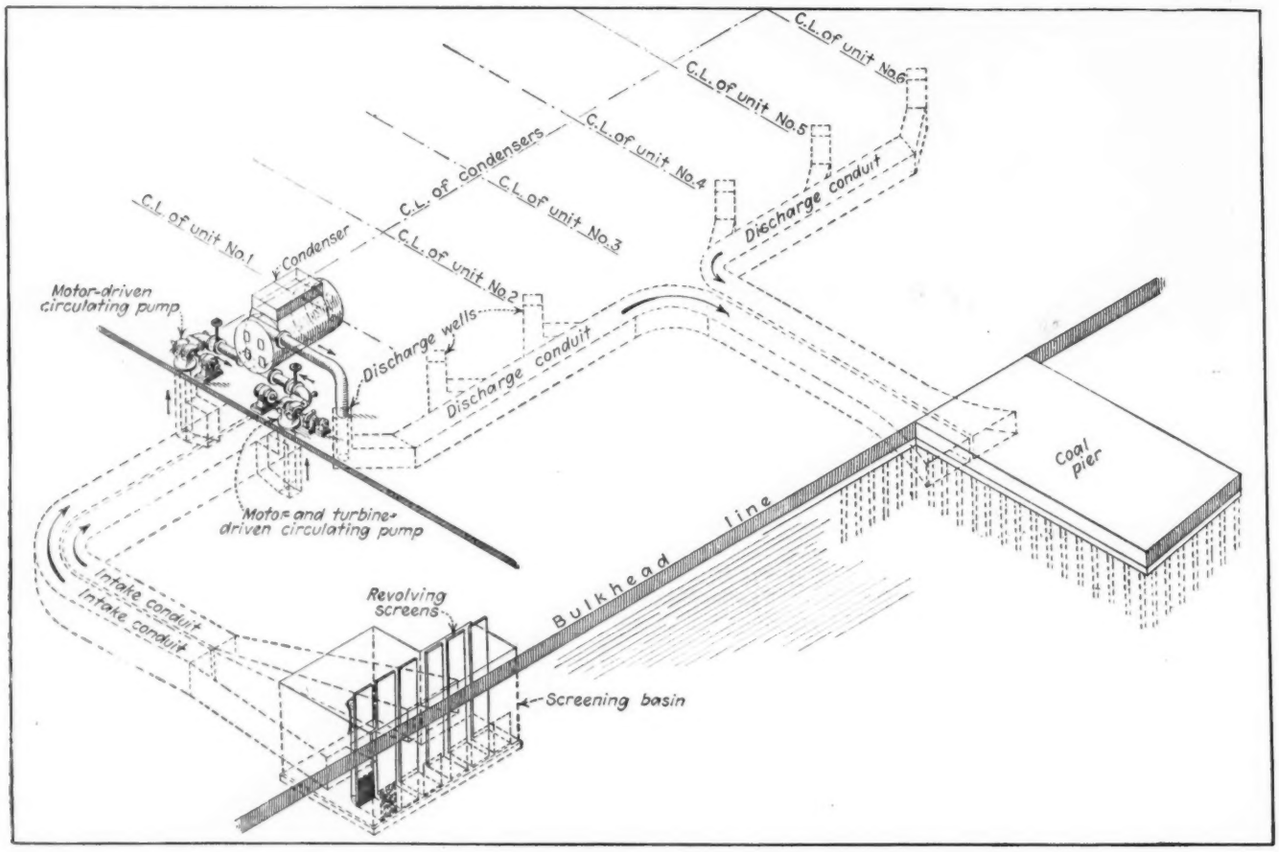


FIG. 7. ISOMETRIC DIAGRAM OF CONDENSER CIRCULATING-WATER SYSTEM

the eleventh stage of the main turbines, but with the flexibility obtainable with the system as designed, it is expected that this method of obtaining heat balance will not be used.

Boilers and Furnaces

There are now installed eight Stirling class M water-tube boilers, 52 tubes wide by 22 tubes deep, divided into four banks, including one bank of five rows designated as an integral economizer. The average length of tube is 18 ft. Ultimately, there will be 24 boilers. Each unit contains 15,080 sq.ft. of heating surface exclusive of the integral economizer, which has 3,750 sq.ft., giving each unit a total of 19,030 sq.ft. Each boiler can be operated up to 330 per cent of normal rating. The feed-water drum, which is on the center line with the mud drum, is 42 in. in diameter and 26 ft. 6 in. long, while the mud drum is 48 in. in diameter by 26 ft. 6 in. long and the steam drums are 42 in. in diameter by 31 ft. long. The superheaters are of the B. & W. type and are located between the first and second tube banks. Each superheater has 1,790 sq.ft. of heating surface and will give 170 deg. F. at normal rating to 220 deg. F. superheat at maximum rating of the boilers. With a boiler pressure of 250 lb. gage this gives a total steam temperature of from 571 to 625 degrees.

For years power-plant engineers have been demanding reserve capacity in equipment, but it remained for the coal crisis during the war to show that the boiler furnace, the very element that these engineers had under their control, lacked any reserve capacity. As long as coal of a high quality could be obtained, the furnaces were capable of getting out of the boilers what they were designed for with a fair degree of satisfaction. But when an attempt was made to burn coal of lower grades and varying quality, it was discovered that the furnaces that were supposed to have sufficient volume, fell down badly, and it was soon realized what a narrow margin of reserve capacity was being allowed in boiler furnaces.

Profiting by the experience with low-grade fuel, the engineers of the Philadelphia Electric Co. decided that the furnaces in Delaware Station should have sufficient reserve capacity to take care of almost any emergency and also to operate at high efficiency considerably above normal rating. Due consideration was given to this feature and also to the possibility of utilizing fuels other than bituminous coal burned on stokers. In working out the furnace, four different designs were devel-

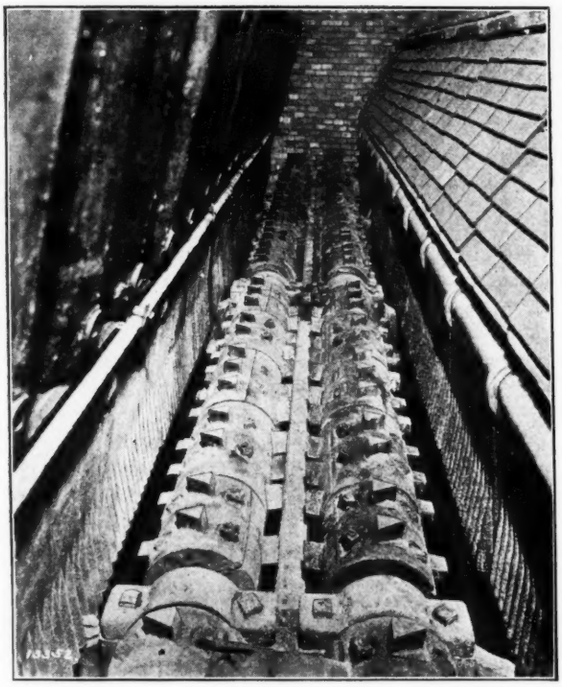


FIG. 8. THE ASH CHAMBER IS PROVIDED WITH CLINKER GRINDER ROLLS

oped—one for burning bituminous coal on stokers, one for powdered bituminous coal, one for powdered anthracite and one for oil. To accomplish this, it was necessary to set the boilers exceptionally high, as is evident from Fig. 10. Figs. 12A to 12C indicate the changes that will be necessary to adapt the furnaces for burning fuels other than bituminous coal on stokers. If it is desired to burn oil, the stokers will be bricked over and the oil burners installed in the back wall of the furnace, as in Fig. 12A. This has been made possible by setting the center line of the mud drum fifteen feet above the boiler-room floor, which allows a clear passageway under the rear of the boiler right up to the back wall. For burning powdered bituminous it will require the removing of the stokers and the lowering of the furnace bottom into the basement, as shown in Fig. 12B. This will also necessitate extending of the front wall of the furnace from a line on a level with the top of the bridge wall out into the firing aisle and installing the burners about midway down the face of this extension. Practically the same arrangement would be used for burning powdered anthracite with the exception of locating the burners (which are brought in at an angle at the top of the extension to the front of the furnace) as in Fig. 12C.

From the foregoing it is evident that the design of the boiler settings might be considered a composite, and this has resulted in a very high setting, giving a ratio of furnace volume to boiler-heating surface of 0.48 to 1. From the boiler-room floor to the center line of the steam drum is 32 ft. 10½ in.

This large furnace volume has resulted in a number of desirable features in operation. More complete combustion is obtained in the furnace, thus eliminating secondary combustion in the boiler passes, with all its evils. It has also been found that the volume of cinders carried up the stack is reduced considerably below that with boiler installations having smaller furnace volume per square foot of heating surface.

Water-backs are installed in the face of the bridge wall of all boilers, with one exception. In the latter air-cooled non-clinkering furnace blocks have been installed for experimental purposes. The furnace walls of this boiler up to the top of the fire are also laid up with these blocks, as shown in Fig. 11.

As shown in Fig. 10 the front wall of the furnace is divided into two parts. The upper portion is supported on an I-beam structure, thus relieving the stoker of considerable weight. The upper end of the lower half of the wall laps inside the lower end of the upper half with a dry joint between. To date the construction has proven very satisfactory.

Firing is done with 15-retort 22-tuyere Taylor stokers. Each stoker has a projected area of 312 sq.ft. and is driven by a 20-hp. direct-current motor. Double-roll clinker grinders are used, driven from the stoker motor.

As already pointed out, the plant is built of reinforced concrete, and effort has been made to reduce the weight on the building structure to a minimum. To this end very short stacks, with induced-draft fans, are used. They are of the self-supporting steel type, 15 ft. 6 in. inside diameter, with their tops 145 ft. high above the firing-aisle floor. Three are now installed, but there will ultimately be eight, one stack serving each row of three boilers of the same type. The flues are on the roof, are constructed of steel

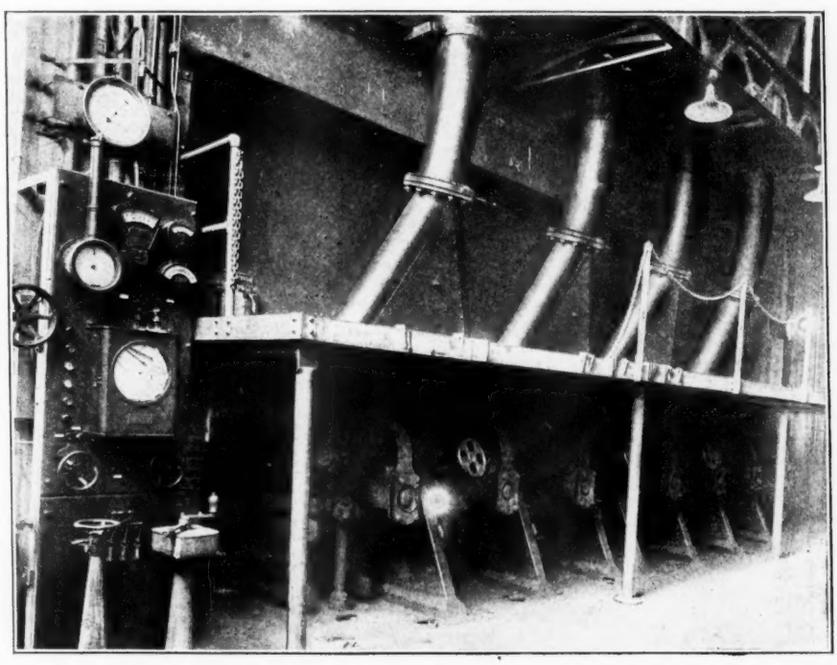


FIG. 9. BOILER IS CONTROL CENTERED IN INSTRUMENT BOARD AT LEFT OF BOILER FRONT

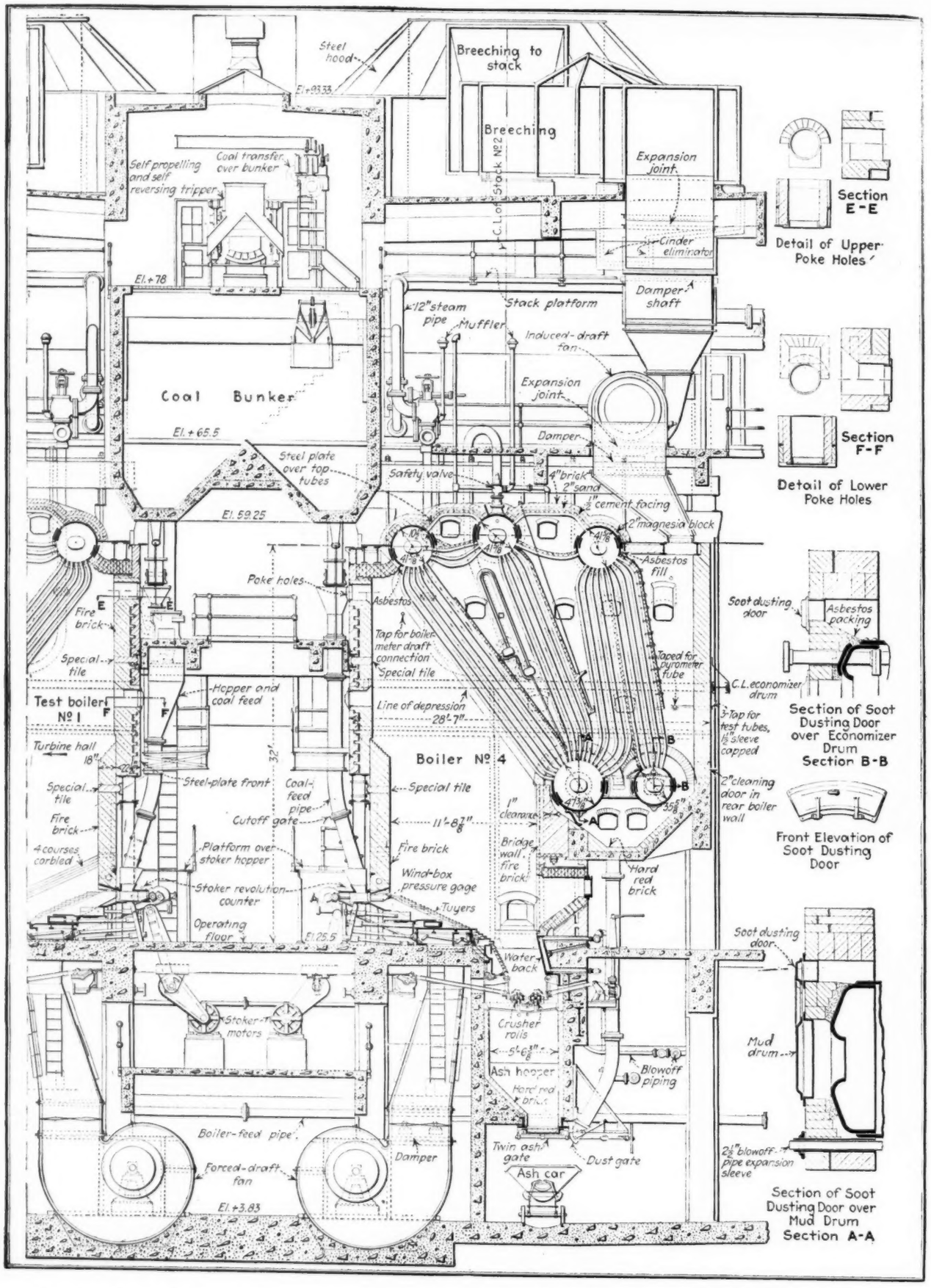


FIG. 10. CROSS-SECTION THROUGH ONE BOILER; NOTE THE HIGH SETTING AND INTEGRAL ECONOMIZER

and are not insulated, insulation not being considered of sufficient value to warrant its use from an economical viewpoint. A section of the breeching in the connection from each boiler was enlarged and constructed so that the gases could be deflected by means of regulating dampers, through a chamber filled with water, where a large percentage of the cinders could be trapped and removed by flushing out the chamber. It was, however, found in operation that with the furnaces as designed in this plant, practically no cinders were passing out through the stacks, and the cinder catchers have therefore not been put into operation.

One forced-draft fan, having a normal capacity of 80,000 cu.ft. per min. against a static head of 6 in. of water, is installed for each boiler. Each fan is driven by a 125-hp. induction motor. Two induced-draft fans are installed over each boiler, each fan having a capacity of 75,000 cu.ft. of gas per min. against a static head of 4 in. of water. Motors for each fan are 100-hp. induction-type, and one fan is sufficient to operate a boiler up to 175 per cent of its normal rating. Above this rating two fans are required. Both fans are installed in a common breeching, but a damper is provided so that either fan may be shunted out of the draft circuit. Since it is intended to operate the boilers below 175 per cent rating except on peak load, only one fan will be in use a large part of the time.

In controlling the draft the wider ranges are secured by varying the speed of the forced- and induced-draft fans and then making the finer adjustments by means of damper regulation. The forced-draft damper, which is located close to the point of control, is manually operated; but the induced-draft dampers, which are at a considerable distance from the boiler-control panel, are motor-operated. The induced-draft damper positions are indicated by means of a series of lamps on the control panel.

Boiler operation is centered in a control board on the boiler-room floor, and the boards for each group of four boilers are located in proximity to one another, so that one man can conveniently take care of the group from one station. One board is provided for each boiler, and is shown in Fig. 9. One boiler, which is classed as a test boiler, has its four coal-feed pipes equipped with individual scales which weigh the coal passing through each pipe.

Boiler-Feed Water System

Four sources of feed-water supply have been provided; namely, the condensate, filtered river water, city water and unfiltered river water (see Fig. 13). The condensate, which is the normal supply, is ordinarily pumped by the condensate pumps through the water backs in the bridge walls of the boilers, where its temperature is increased about ten degrees before going to the feed-water heaters. Or, if desired, for checking the water rate on the main units, the condensate water from any one of the turbines can be pumped through the condensate meter before going to the feed-water heaters. The condensate is metered only at such times as it is desired to obtain the operating condition of the main units, which is for approximately one hour a week per main unit.

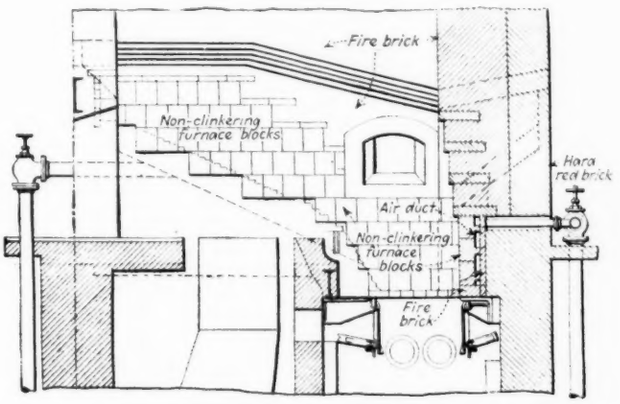


FIG. 11. SECTION THROUGH ONE FURNACE SHOWING NON-CLINKERING FIRE BLOCKS

On the condensate system there is a standpipe *L* in

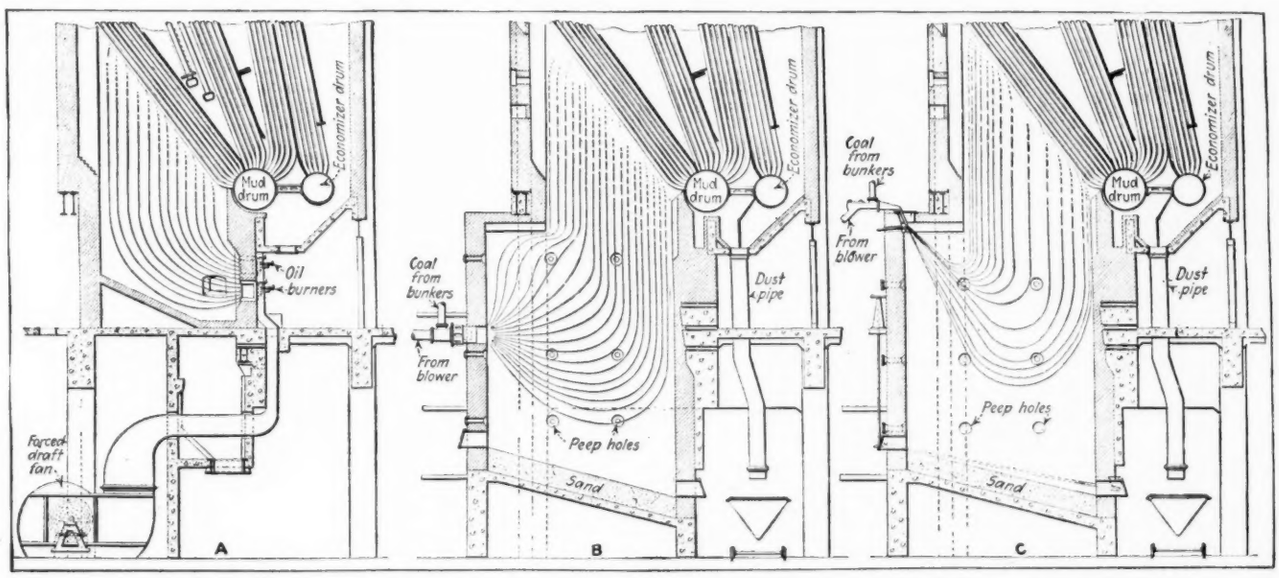


FIG. 12A TO 12C. MODIFICATIONS IN BOILER FURNACE SO AS TO BURN OIL, OR POWDERED COAL

Fig. 12A—Proposed changes in boiler furnace to burn oil. Fig. 12B—Proposed changes to burn powdered bituminous. Fig. 12C—Proposed changes to burn powdered anthracite.

the form of a loop from X to Y. In case the supply of condensate falls to the point where the water in the standpipe comes to the level of float B, this float drops and opens a valve V_1, which turns unfiltered river water into the condensate system, so that at all times there will be a supply of water for the water backs in the boiler bridge wall. This is an emergency condition only, as an alarm has been placed in the loop which operates before the float valve opens, so that the boiler operator can change the source of supply to a sufficient number of water backs to maintain the condensate level above the float valve. The water in the surge tank is maintained at a given level by the float C, which opens valve V_2, when the level drops to about one-third down the tank and admits makeup water.

Two pumps are provided, one motor-driven and one turbine-driven, either one sufficient in capacity to supply this service. River water is pumped through sand filters, then to the makeup meter and then to the feed-water heater surge tank. This water is also used for cooling bearings, etc. Should this source fail and the filtered river water fall in the standpipe below the level of the float shown at A in Fig. 12, this float will drop and open a valve V, admitting city water directly to the makeup system. There are on the city-water supply two storage tanks connected to a standpipe equipped with a float switch. When the city water is turned into the makeup system and the former supply in the storage tanks drawn down to a certain level, the float switch on the standpipe automatically starts up the motor-driven pumps on the city service. Provisions have also been made to use unfiltered river water for boiler feed should the emergency arise. This possibility, however, is very remote.

A special type of valve controls the water to the water backs. When condensate is used, the valve is set in position to allow the water to flow through the water backs and then to the feed-water system. To use river water the valve is set in a position where the water, after flowing through the water backs, goes directly to the circulating-water discharge conduit. This is shown in the diagram at D.

At present it is necessary to raise the temperature of the feed water to about 210 deg. before entering the economizer, to prevent pitting the tubes. Provisions have been made, however, to take the condensate through an air extractor, the fundamental principle of which is to boil the condensate by maintaining a vacuum in a tank through which it passes. By this method it is expected that at least 95 per cent of the air will be removed and allow putting the water into the economizers at around 145 deg. F., which will result in an increased boiler efficiency.

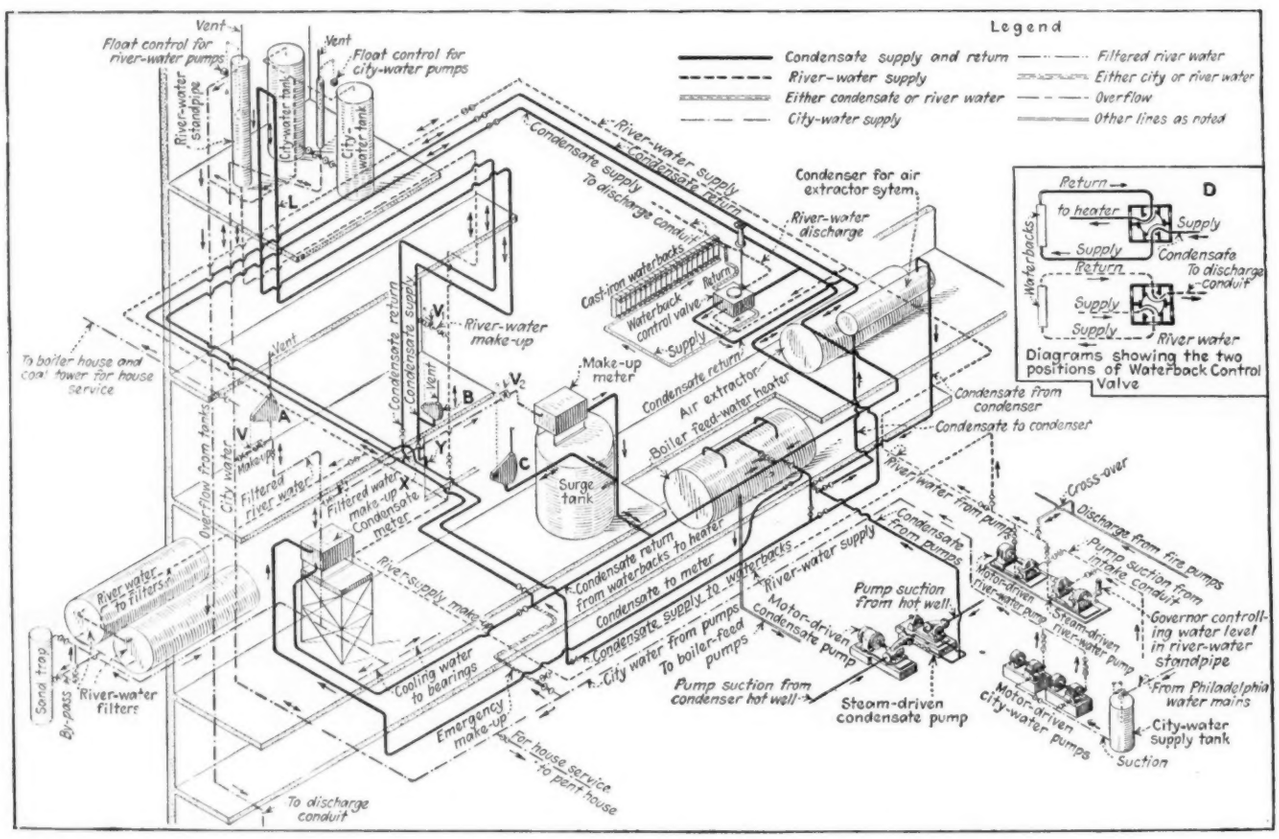


FIG. 13. ISOMETRIC DIAGRAM OF BOILER FEED-WATER SYSTEM

Four boiler-feed pumps, each of 1,000 gal. per min., are installed, all turbine-driven, two for each feed-water heater. Feed-water heaters are of the open type and have a normal rating of 750,000 lb. of water per hour. This quantity of water can be heated from 70 deg. to 210 deg. F.

Coal- and Ash-Handling Equipment

The selection of coal-handling equipment for a power plant will be influenced by the manner in which coal is received—by **rail,** water, or both. If by rail, then

dumping into a track hopper is, in general, the best solution. How the coal will be handled after this is a question of conditions and engineering judgment. When coal is received by water, a hoisting tower is almost a necessity to economical handling. This tower may be of such a height that all the coal-preparing equipment will be above the level of the bunkers, which means that the coal conveyor will be on a level throughout its length. This requires a tower about 200 ft. high and sufficiently strong to support the handling equipment. On the other hand, the tower need be made only of sufficient height to house the preparing and handling equipment, and the coal elevated to the bunkers either by a vertical bucket conveyor and some type of horizontal conveyor, or by an inclined conveyor.

In the solution of this problem at Delaware Station, the latter method was chosen, and the tower was made only high enough to house the handling machinery above the pier floor. The coal tower, like the plant, is of reinforced concrete, consequently if it had been made high enough to house the handling and preparing equipment above the conveyors over the bunkers, a large and expensive structure would have been required.

On account of the limited size of the property it was almost essential that the coal tower be located on a pier extending out into the river. By extending this pier out to the harbor line, ample storage has been obtained for coal and ash boats between the end of the pier and the bulkhead line, so that these boats are protected from all river traffic and the largest coal barges can be trimmed without extending out beyond the pier end. This pier also serves another very essential purpose; that is, it extends out into the river between the intake and discharge end of the circulating-water tunnels and thus prevents the condenser discharge water from ebbing around into the intake. This is clearly shown by Fig. 7. The coal-handling apparatus is in duplicate throughout, located in one building midway between the ends of the pier, as shown in Fig. 13. Two hoisting machines, each driven by a 375-hp. motor and lifting a 1½-ton bucket 90 ft., delivers the coal from boats to hoppers of 30 tons capacity. From the hoppers the coal passes to the picking tables, which are in the form of belt conveyors 42 in. wide by 26 ft. long from center line to center line of pulleys. While being carried on this apron conveyor, all large pieces of metal or other foreign material are removed by an attendant. Small pieces of metal that may be covered by the coal are taken out by a magnetic head pulley located at the discharge end of the conveyor, and go down a débris chute, Ordinarily, the picking table is driven by the crusher motor, but in case of necessity a 5-hp. motor is provided, which is installed so that it can drive either picking table independently of the crusher immediately below it.

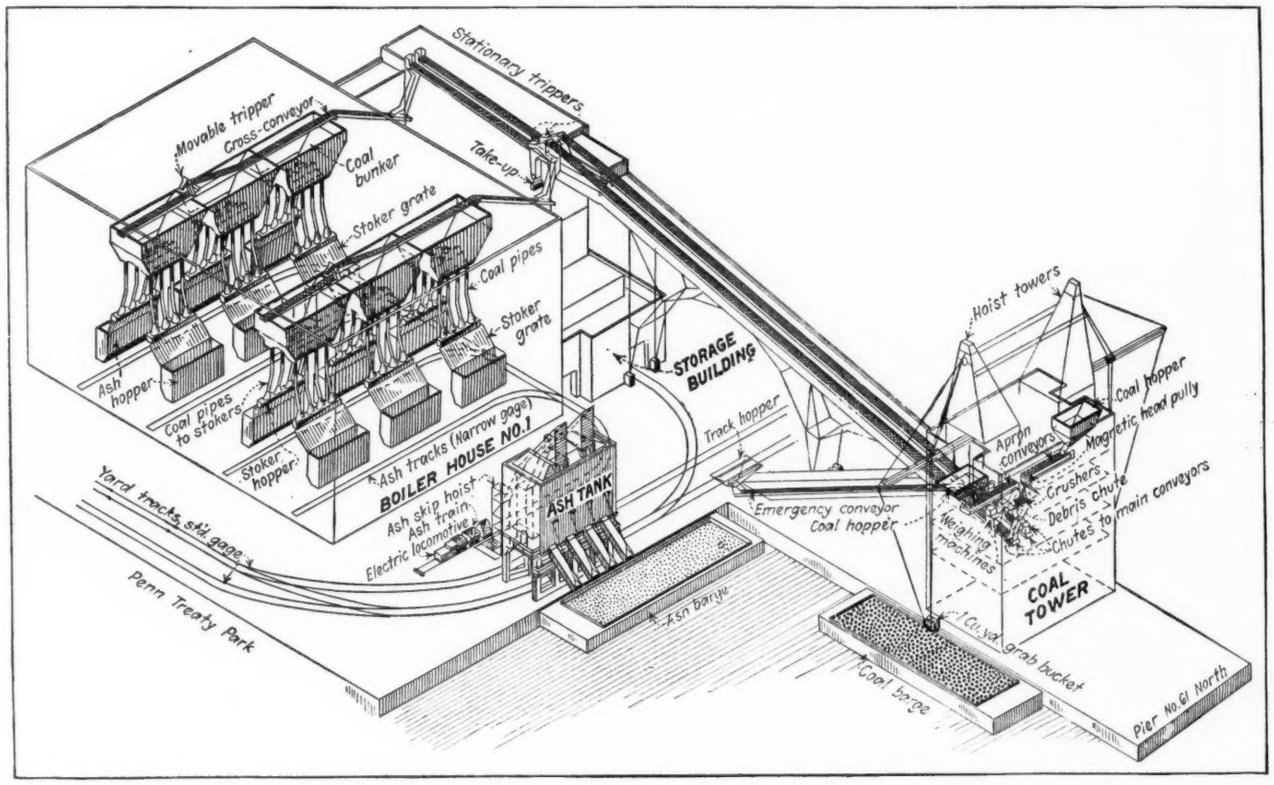


FIG. 14. ISOMETRIC DIAGRAM OF COAL-HANDLING EQUIPMENT

Two double-roll crushers, one for each hoisting machine, each driven by a 75-hp. motor, are located below the picking conveyors. A deflecting apron is provided below the discharge end of the picking table, so that coal discharged from either conveyor can be delivered to either crusher. Coal from either crusher can be deflected to one of the two main belt conveyors, which are installed at an angle of about 13 deg. to the horizontal and run from the coal tower to a level above the bunkers, then continue in a horizontal direction over the storage building. From the main conveyor delivery is made by fixed trippers onto two cross-conveyors which deliver the coal to the bunkers over the

boilers. The main belts are 30 in. wide by 250 ft., center to center line of pulleys, and are driven by 35-hp. motors. The cross-conveyors are 30 in. wide and 172 ft. long, center to center line of pulleys, and are driven by 20-hp. motors. Belt speeds are 350 ft. per min. One-half of this equipment is capable of handling 220 long tons per hour, giving the coal-handling equipment a rated capacity of 440 tons per hour.

Reinforced-concrete bunkers are installed directly above the firing aisle, and each bunker is divided into three sections, each section supplying two boilers, one on either side of the firing aisle. Each section has a capacity of approximately 175 tons, or 525 tons per bunker of three sections, each section serving two boilers. All the aforementioned equipment has been installed except the sampling machines, and when the plant is completed there will be two more cross-conveyors supplying two bunkers similar to those described. The coal-handling system is so designed that the two equipments are interchangeable, and coal may be transferred from one to the other.

A one-man monorail overhead trolley equipped with a clamshell bucket is installed over each coal bunker as an emergency coal-handling equipment, so that in case of fire in one section, where a boiler may be out of service, or when a boiler is out of service and coal is running low in some other section serving a live boiler, transfer can be made.

Coal Bunkers of Small Capacity

It will be noticed that the bunkers are of unusually small capacity, being only about four tons per linear foot against ten tons or higher in other large stations. This feature was influenced by a number of factors. First of all, since the plant is built of reinforced concrete, it was desirable to maintain the loads on the building as low as possible. Therefore, it was decided to use small bunkers and supplement the storage by boats at the coal pier, where there is ample room to store 10,000 tons. The company's main coal storage yard being located only about 3,000 ft. away from the station, on Petty's Island, where 500,000 tons can be stored, leaves small possibility of the supply being interrupted. An emergency supply has been provided for by rail, as shown in Fig. 14. Coal may be dumped directly from railway cars into track hoppers, and transferred by a belt conveyor to the apron conveyor in the coal tower, and from there passed through the same process as the normal supply. An additional factor considered in the decision to use small bunker is the fact that the coal terminal through which most of the coal comes into the city is only a short distance above the plant, on the Delaware River.

Each boiler is provided with reinforced-concrete hard red brick-lined 1,000-cu.ft. capacity ash hoppers, to be fitted with air-operated gates discharging directly into 1½-cu.yd. ash cars, which are hauled by a storage-battery locomotive to the river front, where a skip hoist discharges them into reinforced-concrete ash tanks. From these tanks the ashes can be loaded by gravity into barges, motor trucks or railway cars.

The rating of the main generating units is 30,000 kw. at 90 per cent power factor, 13,200-14,000 volts three-phase 60 cycle 1,800 r.p.m. The windings are Y connected, but both ends are brought out and current transformers installed to give differential relay protection to the machine. The neutral point is made beyond the current transformers and is connected through an oil switch and a four-ohm resistance to ground, it being possible to ground but one generator at a time. The operation of the differential relay, which can only occur upon trouble in the generators or on its cables, opens the main oil switch, field break switch, the neutral oil switch; lights a red signal lamp at the gage board and gives an alarm in the operating room. This immediate disconnection of the unit in the event of trouble is to minimize the extent of damage to the windings and laminations that might result from a breakdown. Should a fire get started, however, water can be sprayed into both ends of the generator extending from pipes inside the end-bells, by connecting it to the fire system of the station through short, quickly attachable lengths of fire hose, which are normally contained in a rack close by, so as to avoid possibility of accidental drenching of the windings.

Excitation of Main Generators

Excitation to the units is normally supplied from 140-kw. 250-volt shaft-end exciters, which are of ample capacity for the maximum requirements of the main unit. Emergency excitation is from a storage battery and motor-generator sets.

Each generator is equipped with an 85,000-cu.ft. per min. air washer. Air may be taken from the outside passageway between the switchhouse and turbine hall or may be partly or completely recirculated. After passing through the generator, the air is discharged downward into ducts leading to the side wall and thence to the roof. A damper on top of each unit is provided so that the warm air may be discharged into the turbine room for heating purposes when necessary, and this is always left slightly open so that any sparks that may be blown out in case of internal fire, will serve as an indication of trouble to the engineer. Four especially constructed peep-holes through the end-bells are also provided for observing the windings.

The change in the 60-cycle load of the Philadelphia Electric Co. system during different parts of the day is so gradual that no automatic voltage regulation is required; however, provision has been made for the installation of a voltage-regulation system in the future, should it be deemed advisable. The control of the voltage is by means of the main field rheostat.

Station Control System

Between the switchhouse and the turbine hall is a connecting building in which are the operating room, pipe room, alternating-current light and power substation, direct-current power and emergency excitation room and operating offices. In the center of the operating room are the main switchboards for controlling the generators and high-tension feeders. The main switchboards consist of the benchboard on which are all the control switches; the instrument board directly in back of it, on which are all instruments that must be under constant observation; and the relay board to the rear containing relays and graphic instruments that need only be occasionally looked at. In addition to the usual instruments and equipment provided for generator and feeder control there is a totalizing graphic wattmeter for indicating as well as graphically recording the total output of the station. There is a drop signal panel on which is indicated, by a small telephone drop accompanied by an audible alarm, the automatic operation of any oil switch, the failure of air pressure at any air-blast transformer, any unbalanced current

that may be flowing, etc. The control system is extensively sectionalized by a number of small knife switches, making it possible to locate trouble on this system in a minimum of time. Below the operating room is a pipe-room where all the conduits containing secondary and control wires are brought and connections between the bench, instrument and relay boards are made. Cutout panels are also located here in order to test instruments and to facilitate the detection of trouble on secondary leads.

The Delaware Station has been designed by the engineering department of the Philadelphia Electric Co. and conforms very closely to that adopted for the Chester and Schuylkill No. 2 generating stations, thus giving a uniformity that is very desirable for the operation of the system as a whole. Those who were to be responsible for the operation of the station were not only consulted regarding the design, but also served as inspectors on the job during construction. In this way a trained operating force, familiar with every detail of the plant, was available when the station was put into service.

Power wishes to acknowledge the assistance and cooperation rendered in the preparation of this article by Joseph B. McCall, president, Walter Johnson, vice-president, and W. C. L. Eglin, chief engineer, of the Philadelphia Electric Co., and other members of this company's engineering department.

TABLE OF PRINCIPAL EQUIPMENT IN DELAWARE STATION

No.	Equipment	Capacity	Type	Manufacturer
2	Turbo-generating units	30,000 kw.	Curtis horizontal	General Elec. Co.
8	Boilers	15,080 sq.ft.	Stirling Class M with integral economizers	Babcock-Wilcox Co.
8	Integral economizers	3,750 sq. ft.		Babcock-Wilcox Co.
8	Superheaters	1,790 sq. ft.		Babcock-Wilcox Co.
16	Clinker grinders		Double roll	American Engineering Co.
8	Stokers		15 retort, 22 tuyere extra width	American Engineering Co.
8	Soot blowers		16 units per boiler	Diamond Power Specialty Co.
8	Forced-draft fans	80,000 cu.ft.p.m.	Radial flow	Green Fuel Economizer Co.
4	Boiler feed pumps	1,000 gal. per min.	3-stage centrifugal double-section	Worthington Pump and Machinery Co.
4	Boiler-feed turbines		Direct connected	Moore Steam Turbine Corp.
2	Feed-water heaters	750,000lb. per hr.	Open	Harrison Safety Boiler Works
	Induced and Forced draft flues		Sheet metal	Dover Boiler Wks. and Connery & Co.
	Pipe covering		85 per cent magnesia	American Insulation Co.
2	Coal crushers	220 tons per hr.	Double roll	Stephens-Adamson Co.
2	Coal-hoisting equipments	220 tons per hr.		Mead-Morrison Mfg. Co.
2	Main coal conveyors	220 tons per hr.	Belt	Stephens-Adamson Co.
2	Cross-conveyors	220 tons per hr.	Belt	Stephens-Adamson Co.
2	Coal weightometers	220 tons per hr.		Merrick Scale Co
4	Coal weighing scales (Test boiler only)	6 tons per hr.		Richardson Scale Co.
16	Ash gates	5 x 2.5 ft.	Air-operated	Baker-Dunbar-Allen Co.
2	Condensers	50,000 sq. ft. ea.	Surface	Westinghouse Electric & Mfg. Co.
3	Stacks	15 ft. 6 in. inside dia. 145 ft. above grates	Self-supporting steel	Coatesville Boiler Works
4	Circulating pumps	37,500 gal. per min.	Centrifugal, two duplex drive, two motor driven	Westinghouse Electric & Mfg. Co.
4	Condensate pump	1,500 gal. per min.	Centrifugal, two motor-driven, two turbine driven	Westinghouse Electric & Mfg. Co.
4	Air pumps	30 cu. ft. per min.	LeBlanc, two turbine driven, two motor driven	Westinghouse Electric & Mfg. Co.
2	Air washers	85,000 cu.ft. per min.		Spray Engineering Co.
1	Oil purifier		DeLaval Centrifugal	Turbine Equipment Co.
6	Intake screens		Revolving	Link Belt Co.
2	Traveling cranes	Main crane 2-45 ton hoists, 1-10-ton auxil. hoist, 1 auxil. crane 10-ton hoist	Electric traveling	Niles-Bement-Pond Co.
1	Condensing-water gate valves	42-in.	Motor-operated	Nelson Valve Co.
2	Atmospheric relief valves	30 in.		Schutte-Koerting Co.
8	Induced-draft flue-damper operators		Motor-driven reduction gear	General Electric Co.
8	Boiler-feed controllers		Copes	Northern Equipment Co.
8	CO_2 recorders			Uehling Instrument Co.
4	Boiler-feed pump governors			Fisher Governor Co.
8	Boiler meters			Bailey Meter Co.
8	Draft gages		Dead-beat	Precision Instrument Co.
2	Elevators		Passenger and Freight	Otis Elevator Co.
2	Lea recorders		V-notch for measuring boiler-feed makeup	Yarnall-Waring Co.
1	Lea recorder		V-notch for measuring condensate	Yarnall-Waring Co.
1	Lea recorder		V-notch for measuring boiler blowdown	Yarnall-Waring Co.
6	Strainers		Twin	Elliott Co.
2	Air compressors		Motor-driven	Worthington Pump & Machinery Co.
2	Steam-flow meters		Integrating, indicating and recording	Republic Flow Meter Co.
2	Steam-flow meters		Indicating and recording	General Electric Co.
3	Oil pumps		Rotary	Goulds Pump Co.
2	River-water pumps	2000 gal per min.	Centrifugal, one turbine-driven, one motor- dr.	Worthington Pump & Machinery Co.
2	Fire pumps	1500 gal. per min.	Centrifugal, one turbine-driven, one motor-dr.	Goulds Pump Co
2	City-water pumps	250 gal. per min.	Centrifugal	Goulds Pump Co
1	Drip pump	80 gal. per min.	Centrifugal	Goulds Pump Co.
2	Master steam gages			Ashton Valve Co
8	Thermometers		Indicating dial	Brown Instrument Co.
2	Throttle trip valves	18 in.	Solenoid-operated quick-closing	Schutte-Koerting Co.
2	Locomotives (ash-handling)		Storage battery	Atlas Car & Mfg Co.
2	Turbine air ducts		Steel plate	Coatesville Boiler Works
2	Man trolleys and grab buckets	¼ ton		Shepard Hoist Co.
1	Complete refrigerating equipment including:			
2	Ammonia compressors		Horizontal dbl.-acting	Penna. Engineering Co.
2	Ammonia condensers			
2	Brine pumps			
2	Drinking-water pumps			
2	Water filters			
1	Drinking-water tank			
2	Ash skip hoists	30 cu. yd. per hr. each		R. H. Beaumont Co.
2	Coal trippers		Fixed	Stephens-Adamson Co.
2	Coal trippers		Traveling	Stephens-Adamson Co.
1	Barge-handling equipment			Mead-Morrison Mfg. Co
2	Vacuum pumps for heating system		American Marsh	American Pump Co.
8	Non-return valves	10 in.		Schutte-Koerting Co.
8	Stoker tachometers			Electric Tachometer Co.
16	Induced-draft fans	75,000 cu.ft.p.m.	Radial-flow	American Blower Co.

High-pressure valves were furnished by the Nelson Valve Co.; Lunkenheimer Co.; Hancock Valve Co., and the Walworth Co.; low-pressure valves were furnished by Pratt & Cady Co. Numerous thermometers and instruments were purchased from the Foxboro Co.; Crosby Steam Gage & Valve Co.; F. Weber & Co.; Jas. G. Biddle; Schade Valve Co.; Builders Iron Foundry and Neptune Meter Co. Piping was purchased from Standard Fitting and Pipe Co. and Whitney-MacDonald Co. Steam traps used were of two types, Squires and Sarco.

Station transformers, General Electric Co.; switches, General Electric Co., Westinghouse Elec. & Mfg. Co., Conduit Electric Co. and Electrical Development and Machine Co.; feeder reactors, General Electric Co., and Westinghouse Elec. & Mfg. Co.; insulators, Electrical Development and Machine Co.; high-voltage testing set, Westinghouse; motors, General Electric and Westinghouse; instruments, Weston Electric Co.; storage batteries, Electric Storage Battery Co.; signal system-Q P. Signal Co.; transformer fans, American Blower Co.; transformer air washer, Spray Engineering Co.

Hydro-Electric Practice—Features of Design

Overall Efficiency of Hydro-Electric Power System—Effects of Main Unit Sizes Upon Station Efficiency—Importance of Specific Speed in Turbine Design—Curves Given for Checking Turbine Design or Laying Out Preliminary Designs

By C. VOETSCH, M.A.S.C.E.
Hydraulic and Electrical Engineer, Hamilton, Ohio

THIS country is particularly favored by nature in abundance of water power, offering us every opportunity to gain experience and adjust our industry to develop these resources properly. This has been done in big strides, and we no longer have to buy our large hydro-electric units from foreign countries as in former days, because they are more advanced in theory and experience, since we are now fully able to co-operate and work with them, in the exchange of science, improvements and innovations in design and practice.

It was only fifteen years ago that core boxes for the runners and the drawings of turbines, governors and auxiliaries were bought from European manufacturers and the machine manufactured by American concerns, or in some cases the entire machine was manufactured abroad and shipped to this country. Today such a procedure would hardly be thought of, since we manufacture the largest hydraulic turbines and their auxiliaries in the world, owing to the available natural resources and our ready market for power.

Our present means of developing water-power resources may be called satisfactory as to good engineering, but when itemizing the over-all efficiency of an overland hydro-electric station and distributing system, a different conclusion is arrived at. A short recapitulation of the various losses in such a plant and its distributing system may be of interest.

	Good Design Per Cent	Poor Design and Long Pipe Lines Per Cent
Loss in racks, intake, pipe line, etc.	2	10
Loss in turbines	6.5 to 10	17
Loss in generators	3 to 4	5
Loss in step-up transformers	1	2
Loss in transmission line	10	15
Loss in step-down transformers	1	2
Loss to distributing centers and substations	3	5
Loss in feeders	10	15
Loss in low tension transformers	5	10
Total efficiency up to customer's meter	62	42

This is a rather unpleasant disclosure, and although during the last few years considerable improvement in efficiency of prime movers and secondary machinery and apparatus has been made, it appears that there is still a large field open for further improvements and refinements. The efficiency of well-designed machinery has approached quite a satisfactory limit, but the transmission and distribution losses still remain high. Copper and aluminum are the best materials at the present time for this purpose, but it is highly desirable to have them replaced by material of still better electric properties and of lower price.

Given the gross quantity of water Q_g in cubic-foot-seconds, and the gross head H_g in feet, and subtracting the losses through the submerged arches, racks, intakes, headgates, pipe line and bends, or whatever resistances occur in a given development, gives the net head H_n acting on the turbine. Subtracting approximately 3 per cent for the exciter units and other auxiliaries

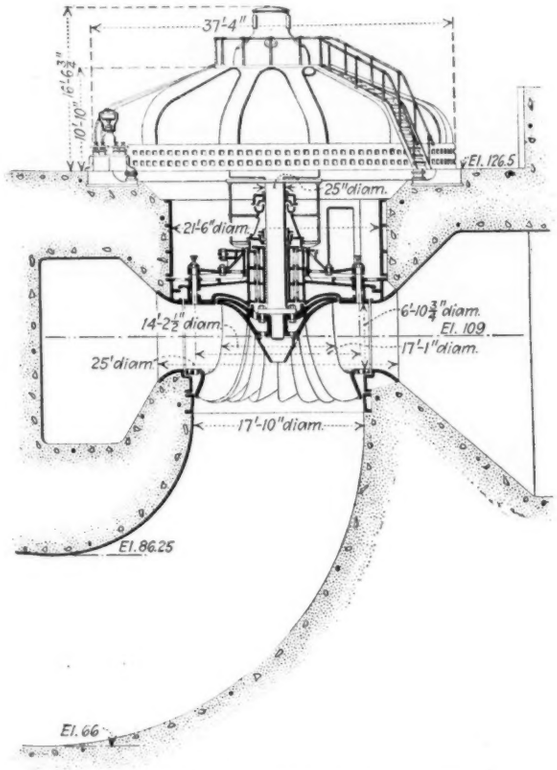


FIG. 1. TURBINE, 10,000-KW. CAPACITY, OPERATING AT 54.3 R.P.M. UNDER 30-FT. HEAD

from the gross amount of water Q_g there will remain the net quantity of water Q_n for the turbines. The available horsepower at the turbine coupling will then be $Hp. = 0.1134 \times Q_n H_n E_t$, or the power in kilowatts available at the switchboard will be $Kw. = 0.1134 \times Q_n H_n E_t E_g \times 0.746$, in which E_t denotes the turbine efficiency and E_g the generator efficiency.

After the determination of the total bulk of power available at the generator terminal, the problem of dividing this power into various units must be solved. This question is a rather complex one, and considerable has been written on the subject. A few main points that enter this consideration may, however, be mentioned. From the viewpoint of operation it is desirable to have a sufficient number of units so that the service will not be crippled in case a unit should be disabled. Where large units are used, if one is taken out of

service, the power supply may be badly crippled, provided there is no spare unit or a steam reserve. In an interconnected system of several water powers, where the power is developed in many units, of course larger and in turn cheaper units per horsepower may be used, also a considerably higher efficiency is obtained with

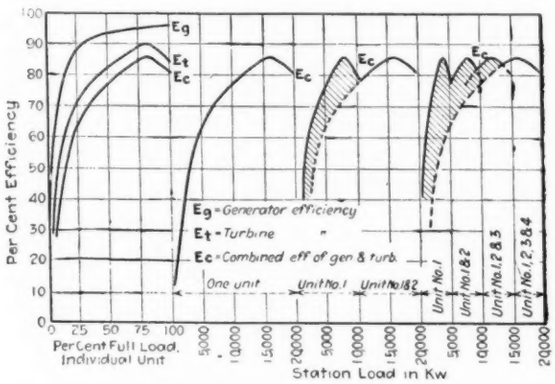


FIG. 2. OPERATING EFFICIENCIES OF STATIONS HAVING ONE, TWO AND FOUR UNITS

larger-sized wheels. This point has also to a great extent caused the recent interconnecting of power systems and the trend to larger units. To an extensive combination of water powers may be added a new water power consisting of one or two large units only. The interconnection further permits a better rate of utilization and distribution of the installed generating capacity. Plants located on streams of different runoff character and storage are able to help one another over peaks, troubles and water shortages and thus eliminate or at least cut the costly steam reserve down.

When considering a single station with one or two units merely as a system unit, it must be borne in mind that the breakdown of one of the machines means a

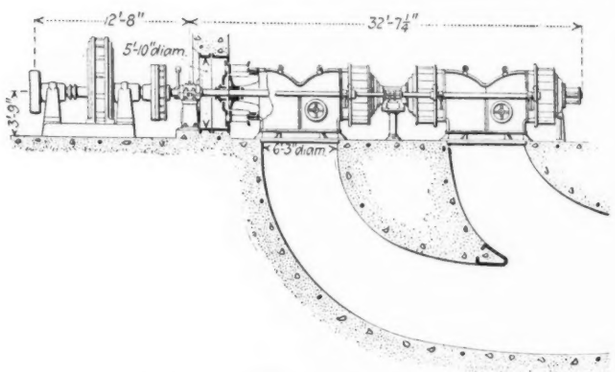


FIG. 3. FOUR-RUNNER 900-HP. TURBINE, OPERATING AT 200 R.P.M.; HEAD 19 FT.

monetary loss as the water cannot be utilized unless storage capacity is available. Hence only the highest reliability of the installation warrants such a concentration of power.

Another point to be considered is the varying efficiency of the unit at different loads even when more than one unit is employed. Assuming, for instance, a plant of 20,000 kw. with the power developed in one unit; in a second plant assume 20,000 kw. developed in two 10,000-kw. units, and in a third assume the 20,000 kw. to be developed in four 5,000-kw. units. It may furthermore be assumed for simplicity's sake that the generators and turbines, although of different size, will practically have the same efficiency curve. Then, if the maximum combined efficiency of generator and turbine for the first installation is 86 per cent occur-

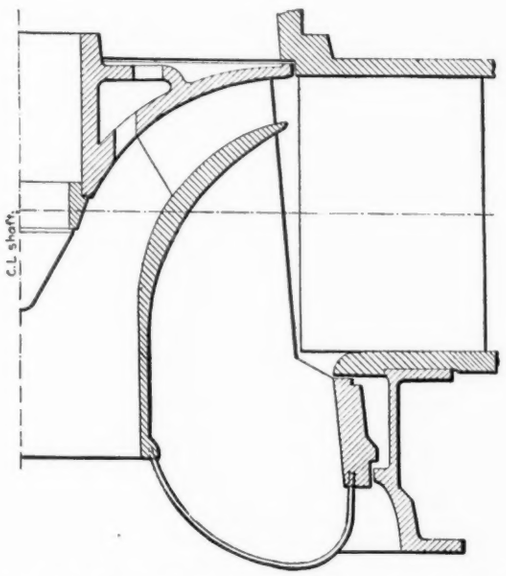


FIG. 4. CROSS-SECTION OF RUNNER BUCKET, WHICH ON TEST SHOWED 93.7 PER CENT EFFICIENCY

ring at 80 per cent load, there is only one load at which this efficiency is obtained. With two units it is possible to operate two different station loads at the maximum efficiency of 86 per cent; namely, one of the

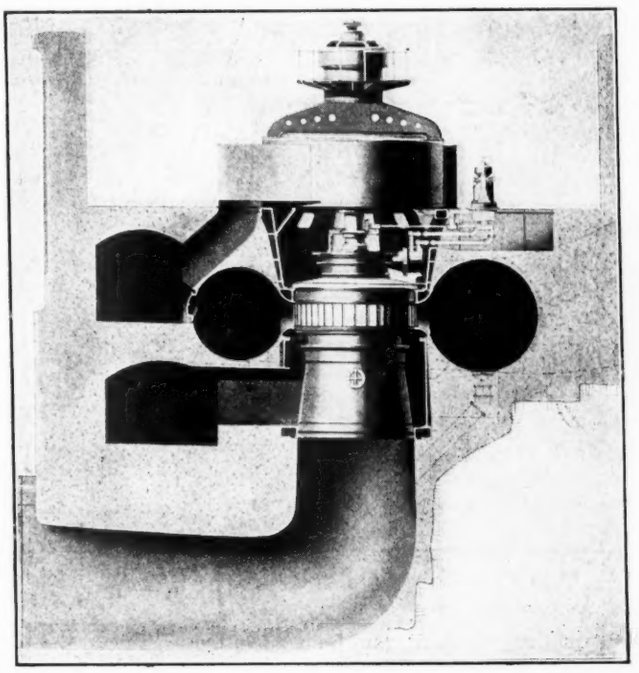


FIG. 5. ONE OF THE 27,000-HP. UNITS; YADKIN RIVER DEVELOPMENT

two 10,000-kw. units at 80 per cent load, or 8,000 kw., or two units together at 16,000 kw., all other combinations of loads and gate openings will work below this

best efficiency. With four 5,000-kw. units four different loads at best efficiency can be obtained; namely, 4,000, 8,000, 12,000 and 16,000 kw. This clearly shows that the over-all operating efficiency of a variable water supply can be utilized more efficiently with four units than with one, two or three only, as indicated in Fig. 2.

In a power plant containing many large units like, for instance, the plant at Keokuk of the Mississippi

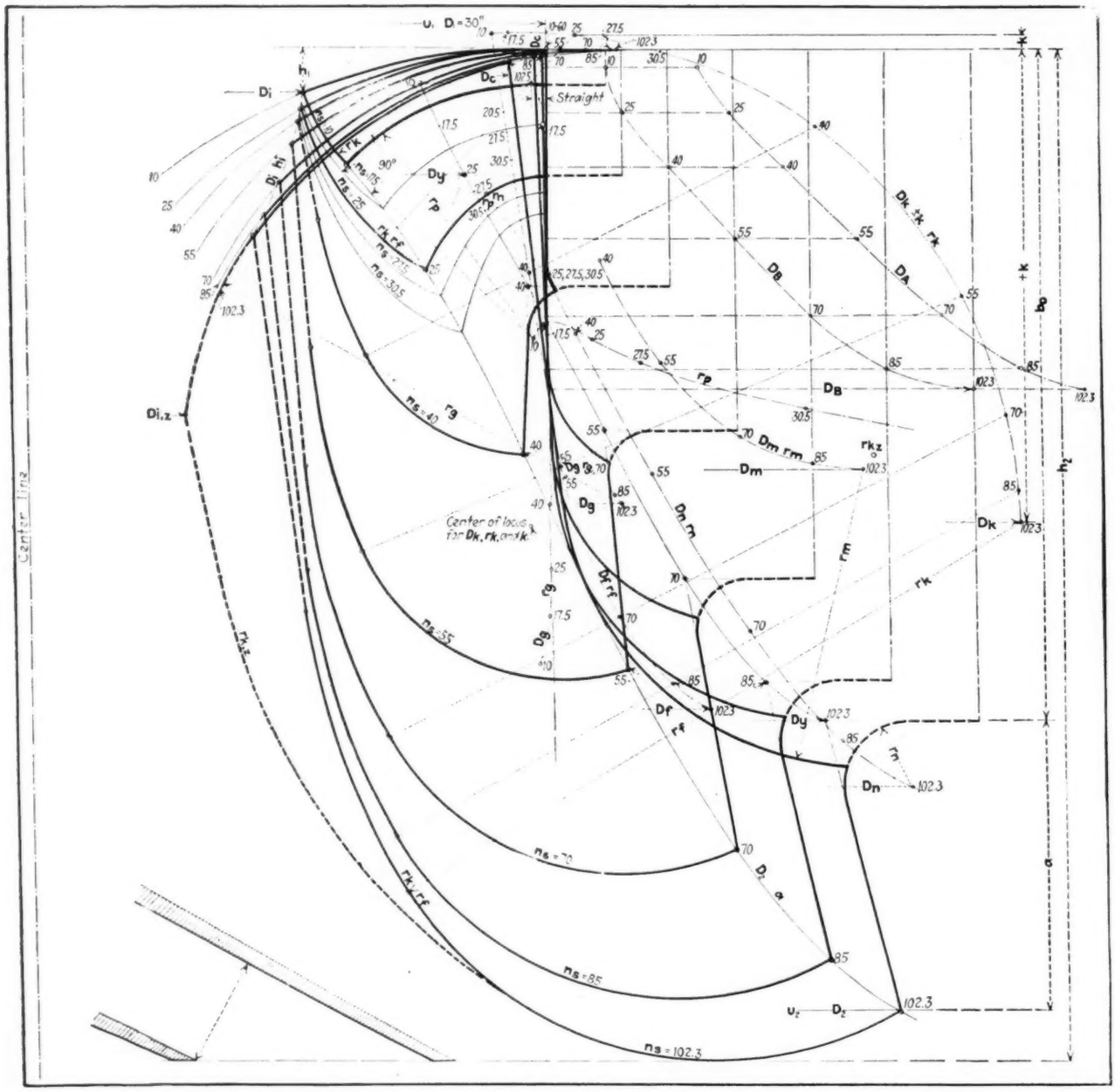


FIG. 6. METAMORPHOSIS OF A 30-IN. FRANCIS RUNNER FOR SPECIFIC SPEEDS OF 10 TO 102.3

Power Co., the load can be varied by throwing in or cutting out entire units, while those in operation are working at their most efficient gate opening. In plants with only a few large units a much more favorable operating diagram can be procured by installing one small unit of about one-half the capacity of the large units. This principle was followed by the writer in the design of a Western plant and works satisfactory and takes particularly good care of low-water conditions. Many types of turbines have been devised, for instance the Girard, Schwamkrug, Jonval and others, but all have practically given way to the two types now exclusively used; namely, the Francis, or reaction type, and the impulse wheel.

The Francis wheel in its present state of development is due in no small degree to the testing flume at Holyoke. In Europe large turbine manufacturers have their own hydraulic laboratories and in this country recently some turbine manufacturers have built their own testing flumes. Besides this, some of our colleges have enlarged and equipped their engineering laboratories with flumes for testing small-sized wheels.

There is in general a keen interest and a healthy rivalry for study and theoretical investigation of the

hydraulic turbine and the various details pertaining to this kind of machinery. The result is that the Francis wheel in particular, up to the highest speeds, is developed to a high state of perfection.

In general runners are classified as low- and high-speed, but the proper term is the "specific speed"[1] of a runner and was first introduced by Professor Camerer, of Munich. The importance of a high specific speed is generally known, as it means smaller and less costly machines. As low heads generally mean low revolutions, the trend to get the highest possible amount of revolutions without sacrifice in efficiency is easy to explain. Formerly, two, four or even six runners were keyed to one horizontal shaft (see Fig. 3) and as high as four runners on a vertical shaft. At present low-head turbines have one large single comparatively high-speed runner, Fig. 1, thus obtaining a simpler, more reliable arrangement and a better efficiency on account of the large size of the runner and also with reference to the draft-tube connection. The vertical arrangement, however, is also frequently used now in high-head plants, particularly in cases where floor space at the bottom of a cliff is limited, Fig. 5. The chief objection raised against the vertical arrangement was the necessary dismantling of the generator in order to gain access to the turbine. In addition to this the former oil-pressure thrust bearing was a difficult thing to deal with. However, both objections have lost in importance on account of the high reliability in the operation of the turbines due to substantial and simple design.

How far this virtue of reliability at the hydraulic prime mover is developed can be realized by the statement that the performance of the three 31,000-hp. units installed in the Badin plant of the Tallassee Power Co. has shown up to the present a continuity factor of 99.992, practically 100 per cent, and the small percentage of time the units were out of service was caused by conditions foreign to the turbines and generators.

[1]Specific speed is the speed at which a turbine would run under a one-foot head if its diameter were such that it would develop one horsepower under that head.

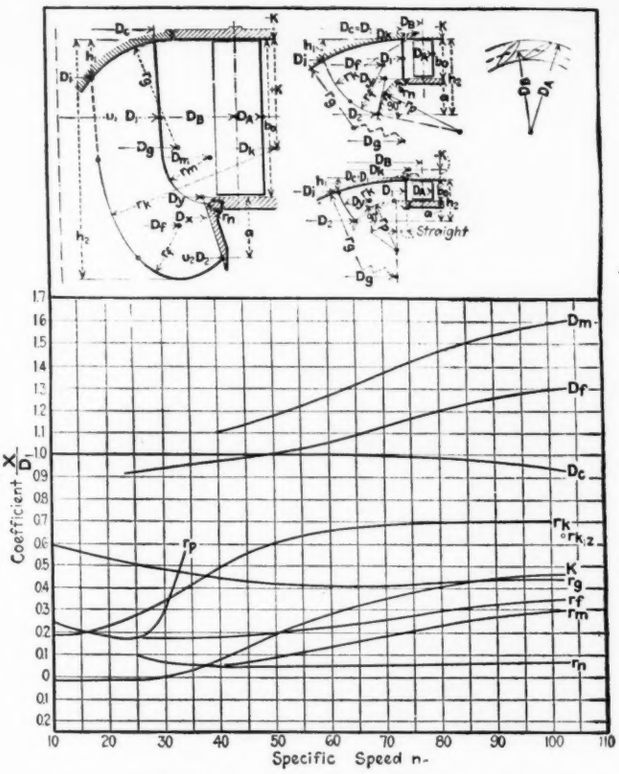


FIG. 8. DIMENSIONS OF RADIAL CROSS-SECTION OF FRANCIS TURBINES REDUCED $D_1 = 1$

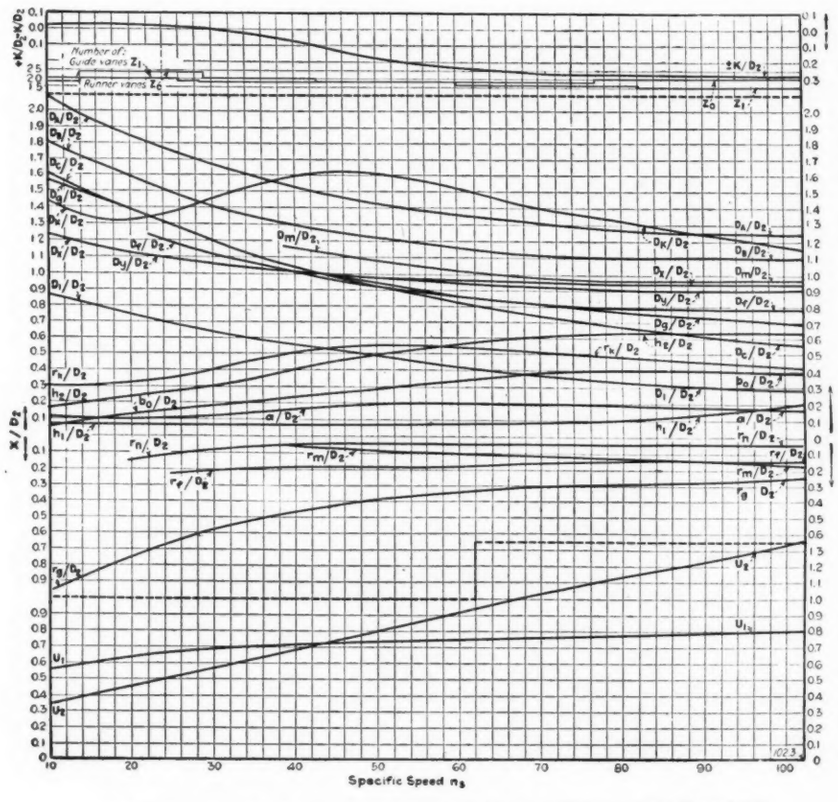


FIG. 7. CURVES OF RUNNER CROSS-SECTION DIMENSIONS BASED ON $D_2 = 1$

The question of the thrust bearing has been solved by the introduction of two different types, therefore little or no trouble is experienced from this source in the modern turbine. An important innovation has been devised for the 27,000-hp. units of the Yadkin River development, Fig. 5. In order to remove the runner and guide vanes without disturbing the rest of the turbine and generator, a telescoping draft tube and pathway was arranged to remove the case and runner from below.

For high heads, runners of low specific speed are used, particularly on account of the corroding effect of the water and the cutting by the suspended solids. The lowest limit of the specific speed may be set at 10 and the highest head under which a Francis wheel has been used is 800 ft. Some manufacturers are willing to recommend Francis-type wheels for heads of 1,000 ft. For heads higher than this the impulse wheel is used only.

The radial cross-section of a Francis wheel designed for a low specific speed of 10 resembles an impeller of a cen-

trifugal pump. The highest specific speed of a Francis wheel was obtained by Professor Zowski; namely, 102.3 with an efficiency of over 90 per cent at part gate. This kind of high specific-speed runners would hardly be used for heads higher than 35 or 40 ft. on account of mechanical strength of the buckets and corrosions near the band.

The highest efficiency obtained up to the present time at the Holyoke Testing Flume was 93.7 per cent, by the Leffel Sparks wheel, Fig. 4, specific speed of 81.

In order to illustrate the variation of the cross-section through the Francis runner on the basis of the specific speed, characteristic data of runners which tested 90 per cent and over at the Holyoke Testing Flume have been collected. In Fig. 6 the smallest cross-section is for a specific speed of 10 The largest cross-section is for a specific speed of 102.3. The drawing therefore shows the metamorphosis of a Francis runner cross-section between these limits. For the power at full gate the vertex of the power curve was taken less 5 per cent, which is the customary allowance for regulation and as an insurance against irregularities in the shop work.

The radial cross-section of the high specific speed of 102.3, as designed by Professor Zowski, is also added in dotted lines and indices z, Fig. 6, for a comparison. The cross-section shows broader features throughout with the exception of the curvature of the crown plate or hub D_e and the over-all height of the runner h_2. The proportions of the various runner cross-sections used as a basis for this derivation have been reduced to unity of D_2, the diameter at the band near the runner discharge, and these proportions plotted in Fig. 7 according to the specific speed of the runner. The nominal diameter D_1, the diameter of the runner at the

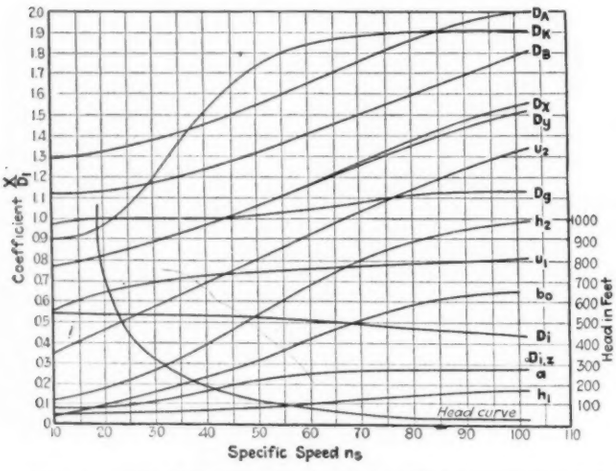


FIG. 9. DIMENSIONS FOR RADIAL CROSS-SECTION OF FRANCIS TURBINES REDUCED TO $D_1 = 1$

center line of the case, and the aforementioned D_2 have been plotted on a basis of their peripheral speed coefficient U_1 and U_2, which is equal to their respective peripheral speeds in feet divided by the spouting velocity $\sqrt{2gH}$. The various groups of points are by no means located on a continuous curve, and the average of these points was taken giving credit to the data which yielded an efficiency considerably higher than 90 per cent. But the points indicated clearly that a distinct crystallization of the best shapes has continuously taken place and led to this investigation.

From the curves based on D_2 a new set of curves, Figs. 8 and 9, were plotted in which the runner proportions are reduced to D_1 for convenience. In Fig. 6 the continuation of the rounding rn at the band is made by means of a curve; the same is the case at the hub. Furthermore, a small allowance may be made with the radii rg and rn in order to make the runner slightly higher than the case for adjustment purposes.

It is understood that the curves presented in Figs. 8 and 9 cover only the radial cross-section of the runner

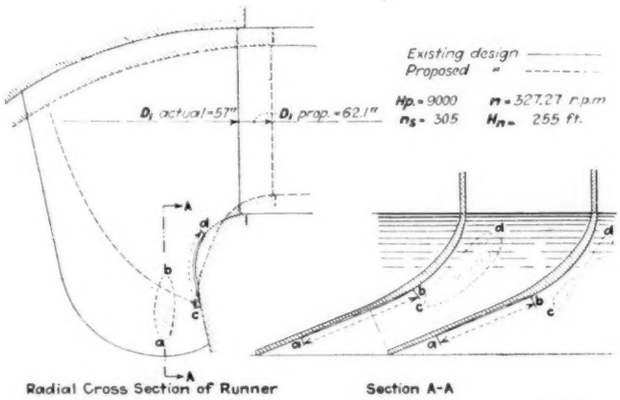


FIG. 10. CROSS-SECTION OF BUCKET FOR A 9,000-HP. FRANCIS TURBINE; PROPOSED AND ACTUAL DESIGN

and present a handy means for laying out proposals and the first assumption for a new design.

In Fig. 9 a curve is plotted showing the safe limits for the specific speed at a given head. Going beyond this specific-speed limit may cause trouble due to corrosion, particularly in the neighborhood of the band, where the sharpest curvatures exist and therefore the greatest danger of the water leaving the walls and forming a space with eddies under vacuum. Such spaces, of course, can be caused by poor design of the buckets proper and, furthermore, occur when the turbine is operated at part gate for a considerable length of time. The latter is the case when a runner is designated too large for the generator capacity, which besides this means a poor part-gate efficiency.

The following example will illustrate the process of attacking a given problem:

Given net head $H_n = 100$ ft., water available $Q_n = 300$ cu.-ft.-sec. per turbine. Assuming the turbine efficiency to be 90 per cent, then the power delivered to the turbine shaft is

$$Hp. = 0.1134 \times Q_n \times H_n \times E_t = 0.1134 \times 100 \times 300 \times 0.9 = 3{,}060 \textit{ horsepower.}$$

For the head $H_n = 100$ ft. the high limit for the specific speed ns is found in Fig. 9 to be 54.6.

From the well-known formula for the specific speed,

$$n_s = n \frac{\sqrt{Hp}}{H_n \sqrt[4]{H_n}}$$

we find the r.p.m. of the turbine to be

$$n = n_s \frac{H_n \sqrt[4]{H_n}}{\sqrt{Hp}} = 54.6 \frac{100 \sqrt[4]{100}}{\sqrt{3{,}060}} = 54.6 \times 5.72 = 312 \textit{ r.p.m.}$$

If, now, the turbine is to drive a 60-cycle alternator, the nearest synchronous speed is $n = 300$ (24 poles).

Adopting this speed then the specific speed will have to be refigured and is

$$n_s = 300\,\frac{\sqrt{3{,}060}}{100\,\sqrt[4]{100}} = \frac{300}{5.72} = 52.5$$

From Fig. 9 find for this specific speed the peripheral

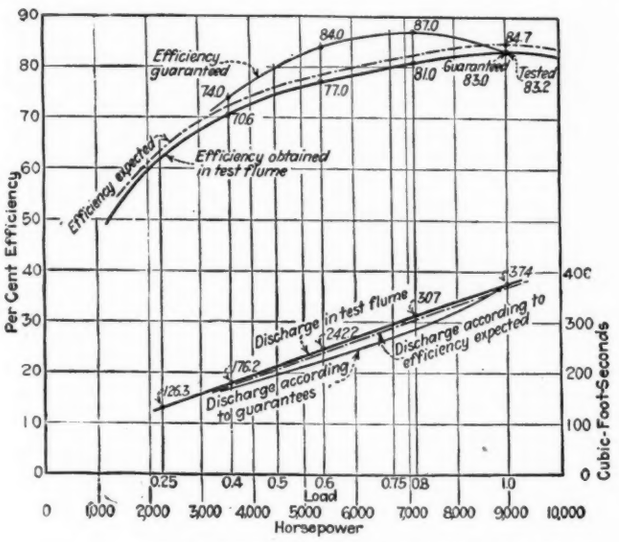


FIG. 11. CHARACTERISTIC CURVES OF A 9,000-HP. FRANCIS TURBINE

speed coefficient $U_1 = 0.746$ and $U_2 = 0.831$ and from the formula

$$U_1 = \frac{D_1 \pi n}{60\,\sqrt{2gH_n}}$$

in which D_1 is the runner diameter, then

$$D_1 = \frac{60\,U_1\sqrt{2gH_n}}{\pi n} = \frac{60 \times 0.746\sqrt{2 \times 32.32 \times 100}}{3.1416 \times 300}$$

$$= 3.805 \textit{ feet} \text{ or } 45.66 \textit{ inches}$$

$$D_2 = D_1\frac{U_2}{U_1} = 45.66\,\frac{0.831}{0.746} = 50.85 \textit{ inches}$$

All the rest of the proportions of the dimensions for the runner cross-section pertaining to the specific speed $n_s = 52.5$ can easily be obtained from Figs. 8 and 9, and when multiplied with $D_1 = 45.66$ in. give the actual dimensions; for example, the height of the runner case $b_0 = 0.335 \times 45.66 = 15.3$ inches.

A typical case at hand, which will serve to illustrate the foregoing, is a hydro-electric station that was equipped with two 9,000-hp. turbines running at 327.27 r.p.m., 60-cycles, under 255-ft. head, and designed for a specific speed of $n_s = 30.5$. The radial cross-section of the installed runner is reproduced in full lines in Fig. 10. In dotted lines in this figure is shown the runner cross-section of proper design as deduced from Fig. 6 and the curves shown in Figs. 8 and 9. After about 14 months of operation the wheel showed strong corrosion about $\frac{1}{8}$ in. deep in two places on the buckets, as is indicated by the shaded areas in Fig. 10. It is evident that the curvature at the band is too sharp for a high water velocity occurring in a runner under a head of 255 ft. Using bronze instead of cast iron or even Monel metal can only retard but not eliminate these oxidizations. The only cure is the redesign of the runner and case, which sometimes is a costly affair if possible at all. This defective runner was tested at Holyoke, and the test results are reproduced in Fig. 11. The vertex of the efficiency curve is at full gate, dropping off toward part load to 81 per cent instead of rising to the guaranteed 87 per cent at 0.8 load. In fact, the whirl in the draft tube does not change its direction when reducing the load from full gate, which is clear evidence that the water does not leave the buckets perpendicularly at any load, but swirls at every gate opening in the direction of the peripheral speed. The turbine could easily develop 12,000 to 12,500 hp. Evidently, the designer was too cautious with reference to power, which proved to be detrimental in regard to corrosions and efficiency. The lack in efficiency is of course of no importance during the high-water season (in this case for about 3½ months), but will result in a loss of power for the rest of the year when water is scarce. The loss in power is in this case about 600 kw. This amount represents a loss of 1,275,000 kw.-hr. to be replaced by steam. Compared with the cost of producing power from coal this represents at least $15,000 per annum entirely due to lack in efficiency, and is an item large enough to warrant the redesign of the runner. Considering that there are many plants in the country that are in similar condition, it is evident that there is a large waste and a good opportunity for reconstruction right in the prime mover itself.

As an illustration of the extreme sizes of hydraulic turbines the two single-runner vertical-shaft cast-

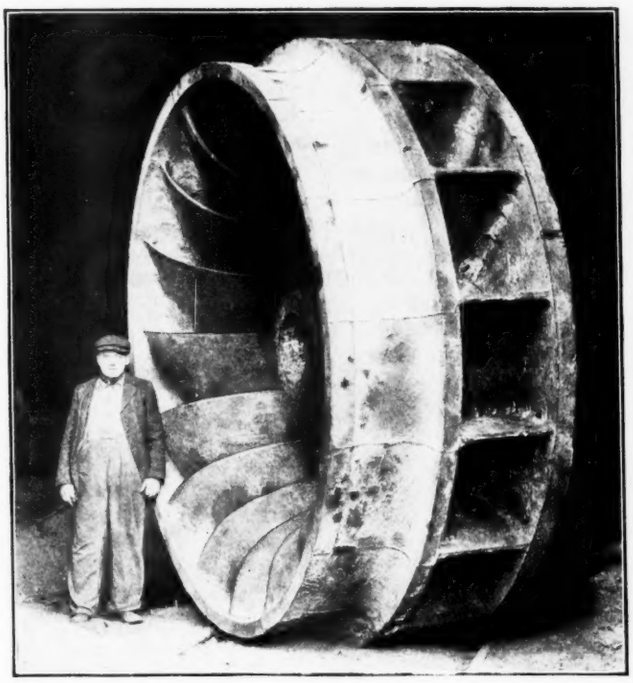


FIG. 12. RUNNER FOR 55,000-HP. TURBINE

steel spiral-casing units for the Queenston plant of the Hydro-Electric Power Commission of Ontario at Niagara Falls are being installed. Each unit will develop 55,000 hp. under a head of 305 ft. Fig. 12 shows one of the unfinished cast-steel runners 125-in. diameter. The runner can be replaced through the draft tube similar to Fig. 5. Three more of these units are on order. Many other examples could be given beside those mentioned in this article.

Heat-Balance Study of Colfax Power Station

By W. P. GAVIT*

IN EVERY power station there are, of necessity, certain auxiliary machines for which power must be furnished. These machines may be steam- or motor-driven, the choice depending on the economic efficiency of heat utilization. From a purely theoretical point of view the most efficient arrangement is to drive all auxiliary apparatus electrically, the current for such drive being furnished by the main generating unit. In the operation of steam turbines with condensers, the latent heat in the steam entering the condenser is not available for conversion into power. If a method can be found for conserving any part of this latent heat, it must improve the over-all efficiency of the system. If, with all the auxiliaries driven electrically, as already mentioned, a certain part of the steam is removed from the main turbine at or near atmospheric pressure and is condensed with the condensate from the main unit and makeup boiler-feed water, this quantity of heat energy will remain in the system rather than be discharged with the circulating water. Then the power for auxiliary drives will be produced at an expenditure of about 11 pounds per kilowatt-hour, instead of from 20 to 40 pounds.

Thermal efficiency attained in a power-producing system. Highest thermal efficiency obtained in plants where all auxiliaries are electrically driven and feed water heated by bleeding main turbines. Heat-balance in Colfax Station of Duquesne Light Co. described and details given regarding heat distribution. Thermal efficiency of Colfax 18.46 compared with 20.2 for the ideal power station.

By removing steam at atmospheric pressure, there is taken from the turbine only that part of the total available energy which is secured in expanding the steam from atmospheric pressure to exhaust pressure. This part is approximately 45 per cent of the total available heat in the steam at 260 lb. gage and 175 deg. F. superheat, the steam conditions assumed in this discussion. For every pound so removed, there must be added at the turbine inlet 0.45 of a pound at full pressure and superheat.

Fig. 1 is a heat-cycle diagram based on the foregoing system. It is for a 60,000-kw. unit having a normal water rate at 50,000-kw. load, with steam at 260 lb. gage and 175 deg. F. superheat, exhausting to a 29-in. vacuum, of 10.58 lb. When the required quantity of steam is extracted (66,000 lb. per hour), the water rate becomes 11.16 pounds.

The condensate is carried directly to an open feed-water heater, where it is heated along with the makeup by steam at 18-lb. gage extracted from the main unit. The water losses in the system have been taken at the low figure of 10,000 lb. per hour, because of the absence of all auxiliary steam and exhaust piping and the extreme simplicity of the entire piping system. Radiation losses in the water system have not been considered, as they would be relatively small and have but a slight effect upon the ultimate economy.

This scheme is open to the objection that in case of disturbances on the distribution system there would be liability of a shutdown of the motors driving the auxiliaries. This, of course, would result in considerable delay in starting after a shutdown, and owing to the fact that there would probably be heavy fires in the boilers from which the draft would be cut off, damage to the stoker equipment would result. The boilers and settings would be at a high temperature, thus continuing the evaporation of water which would escape through the safety valves. In the absence of means for furnishing boiler feed, the water in the boilers would run low and damage would result. For these reasons, except in special cases the scheme is not practical.

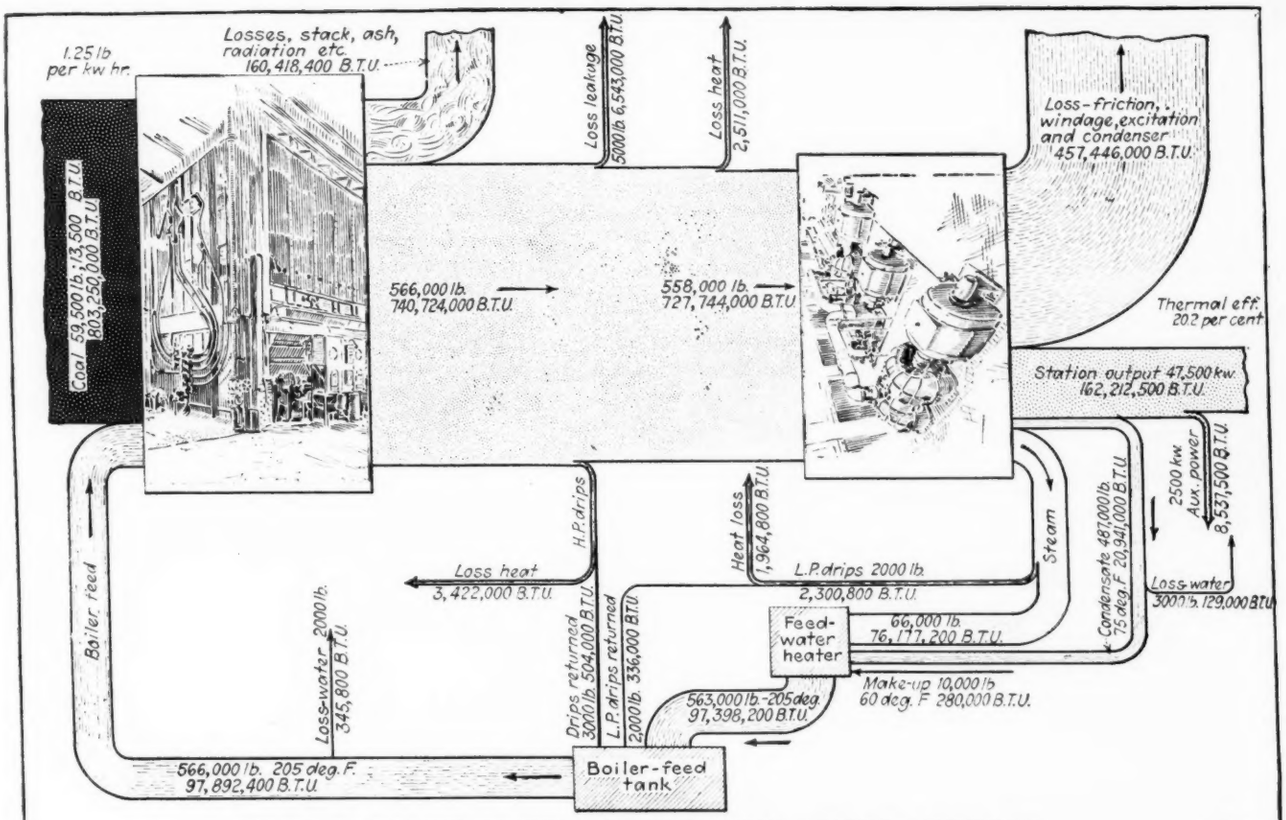
If all auxiliary apparatus is steam-driven, the exhaust being used for the heating of feed water, it is necessary, in order to avoid waste of heat, to have the amount of exhaust available for feed-water heating not in excess of the quantity required. It is, of course, desirable that the feed water entering the boilers be as hot as possible, so that if the available exhaust is very much less than the quantity required to heat the water to 205 or 210 deg. F. the conditions are not in any sense satisfactory. It will be seen, then, that with steam auxiliaries a very nice proportioning is necessary. This in most cases is difficult of accomplishment.

But assuming a proper balance, so that the available exhaust is exactly the quantity required for feed-water heating, the average water rate of the steam-driven auxiliaries will be in the neighborhood of 35 lb. per kw.-hr. equivalent, while, as previously stated, the average water rate per kilowatt-hour from the main unit will not greatly exceed 11 lb. Here is a difference of 24 lb. of steam per kilowatt-hour equivalent for the auxiliary power.

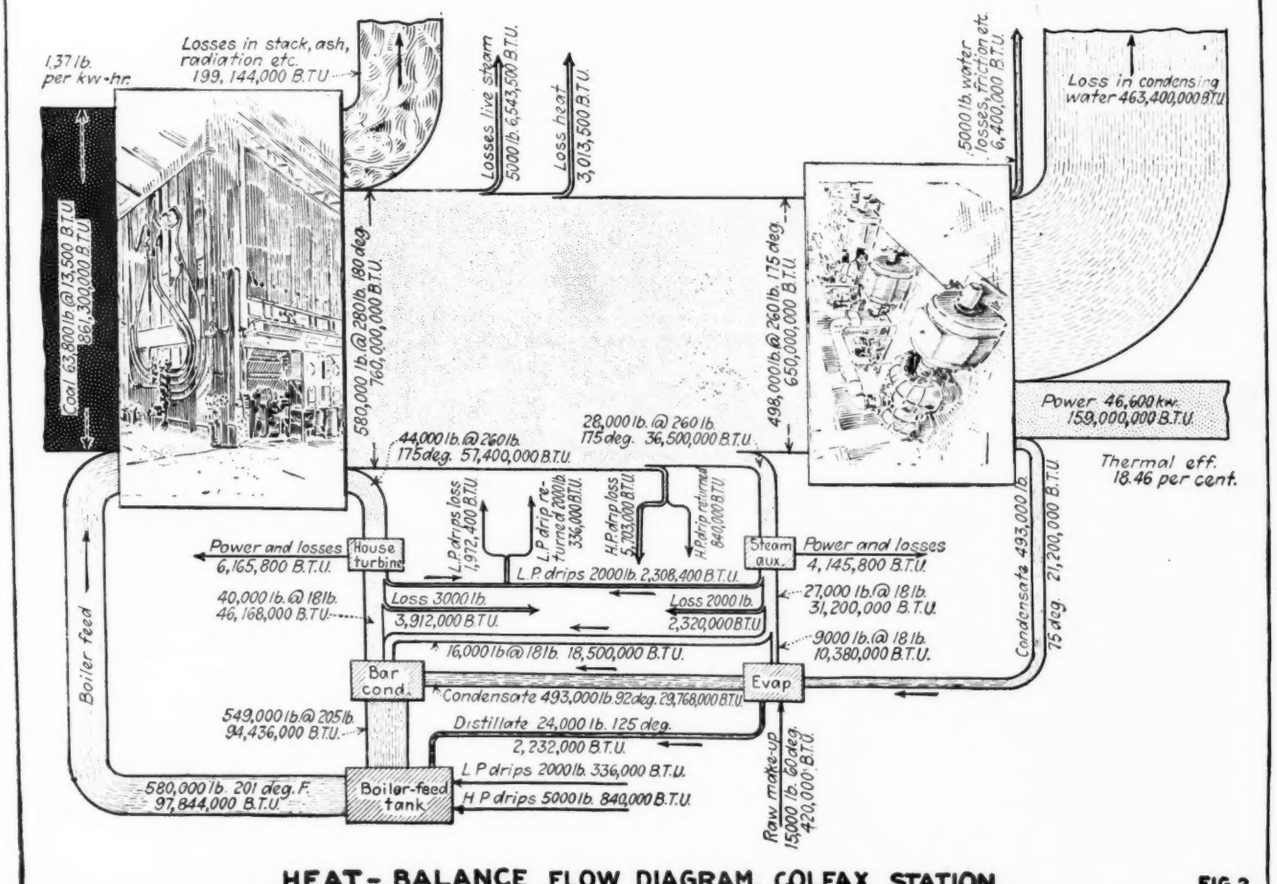
It has been held by many engineers in the past that efficient drive for auxiliaries is of no importance, since all the exhaust steam from this equipment is used in heating the feed water. It is true that all the heat not converted into work or lost by radiation is returned to the boiler in the feed water. So it is when an injector is used, but it does not follow that the use of an injector is the best way to feed a boiler.

It is apparent, then, that the highest economic efficiency will be attained by a compromise between the driving of all auxiliary equipment by steam, the exhaust steam being used for feed-water heating, and a system wherein the auxiliaries are motor-driven, steam for feed-water heating being extracted from the lower stages of the main unit. In the Colfax power station of the Duquesne Light Co. an attempt has been made to accomplish this result. The boiler-feed pumps and forced-draft fans are the only steam-driven auxiliaries in the station. In order to protect the motor-driven auxiliaries from outside disturbances, a separate house bus is provided, fed by a 2,000-kw. turbo-generator, known as a "house turbine." The exhaust steam from this turbine is condensed in a barometric condenser, using the condensate from the main unit for cooling water, this condenser acting as a boiler-feed water heater.

*Dwight P. Robinson and Co., Inc., Engineers and Contractors, New York City.


1.25 lb per kw hr.
Losses, stack, ash, radiation etc. 160,418,400 B.T.U.
Loss leakage 5000 lb 6,543,000 B.T.U.
Loss heat 2,511,000 B.T.U.
Loss-friction, windage, excitation and condenser 457,446,000 B.T.U.
Coal 59,500 lb.; 13,500 B.T.U. 803,250,000 B.T.U.
566,000 lb. 740,724,000 B.T.U.
558,000 lb. 727,744,000 B.T.U.
Thermal eff. 20.2 per cent
Station output 47,500 kw. 162,212,500 B.T.U.
2500 kw Aux. power 8,537,500 B.T.U.
Heat loss 1,964,800 B.T.U.
H.P. drips
Loss heat 3,422,000 B.T.U.
L.P. drips 2000 lb. 2,300,800 B.T.U.
Steam
Condensate 487,000 lb. 75 deg. F 20,941,000 B.T.U.
Loss-water 3000 lb. 129,000 B.T.U.
Boiler feed
Loss-water 2000 lb. 345,800 B.T.U.
Drips returned 3000 lb 504,000 B.T.U.
L.P. drips returned 2000 lb 336,000 B.T.U.
Feed-water heater
66,000 lb. 76,177,200 B.T.U.
Make-up 10,000 lb 60 deg. F 280,000 B.T.U.
563,000 lb.-205 deg 97,398,200 B.T.U.
566,000 lb. 205 deg. F. 97,892,400 B.T.U.
Boiler-feed tank

HEAT - BALANCE FLOW DIAGRAM, IDEAL POWER STATION FIG. 1


1.37 lb per kw-hr.
Losses in stack, ash, radiation etc. 199,144,000 B.T.U.
Losses live steam 5000 lb 6,543,500 B.T.U.
Loss heat 3,013,500 B.T.U.
5000 lb water losses, friction etc. 6,400,000 B.T.U.
Loss in condensing water 463,400,000 B.T.U.
Coal 63,800 lb @ 13,500 B.T.U. 861,300,000 B.T.U.
580,000 lb @ 280 lb 180 deg 760,000,000 B.T.U.
498,000 lb @ 260 lb 175 deg. 650,000,000 B.T.U.
Power 46,600 kw. 159,000,000 B.T.U.
28,000 lb. @ 260 lb 175 deg. 36,500,000 B.T.U.
44,000 lb. @ 260 lb 175 deg. 57,400,000 B.T.U.
Thermal eff. 18.46 per cent.
L.P. drips loss 1,912,400 B.T.U.
L.P. drip returned 2000 lb 336,000 B.T.U.
H.P. drip loss 5,103,000 B.T.U.
H.P. drip returned 840,000 B.T.U.
Power and losses 6,165,800 B.T.U.
House turbine
Steam aux.
Power and losses 4,145,800 B.T.U.
L.P. drips 2000 lb. 2,308,400 B.T.U.
Condensate 493,000 lb. 75 deg. 21,200,000 B.T.U.
40,000 lb. @ 18 lb. 46,168,000 B.T.U.
Loss 3000 lb. 3,912,000 B.T.U.
Loss 2000 lb. 2,320,000 B.T.U.
27,000 lb. @ 18 lb. 31,200,000 B.T.U.
9000 lb. @ 18 lb. 10,380,000 B.T.U.
16,000 lb @ 18 lb. 18,500,000 B.T.U.
Boiler feed
Bar cond.
Evap
Condensate 493,000 lb 92 deg. 29,768,000 B.T.U.
549,000 lb @ 205 lb 94,436,000 B.T.U.
Distillate 24,000 lb. 125 deg. 2,232,000 B.T.U.
L.P. drips 2000 lb. 336,000 B.T.U.
580,000 lb. 201 deg. F. 97,844,000 B.T.U.
Boiler-feed tank
H.P. drips 5000 lb. 840,000 B.T.U.
Raw make-up 15,000 lb. 60 deg. 420,000 B.T.U.

HEAT - BALANCE FLOW DIAGRAM, COLFAX STATION FIG. 2

On account of the lack of pure water for boiler-feed purposes, it was found necessary to install equipment for evaporating sufficient water to make up the losses in the station. This evaporator is of the Lillie dry-tube double-effect type and is guaranteed to evaporate 1.64 lb. of water per pound of steam supplied to it. Steam for this equipment is furnished by the exhaust from the forced-draft fans and boiler-feed pumps. The condensate from the main unit is carried through the evaporator condenser before it goes to the barometric condensers mentioned. Virtually all of the heat supplied to the evaporator is retained either in the distillate or the condensate, the only losses being radiation and blow-down. It is evident that the amount of exhaust steam available from the forced-draft fans and boiler-feed pumps could not in practice be kept exactly right for the evaporator demand. In order that this excess steam would not be lost, a flow or back-pressure valve is provided, permitting any excess steam in the auxiliary exhaust header to flow into the barometric condenser along with the house-turbine exhaust. Fig. 3 is a general single-line diagram of the heat-balance system for the Colfax plant.

With the system as so far outlined, the quantity of exhaust steam going to the barometric condenser could not at all times be a proper amount for heating the boiler-feed water to the desired temperature. In order to regulate the quantity of exhaust steam for feed-water heating purposes, a means had to be provided for varying the load on the house turbine. The simplest way to accomplish this would be to parallel the 2,300-volt house bus with the main station bus through a transformer bank and vary the speed of the house turbine, but on account of the difference in characteristics between the main units and the house turbine, parallel operation of the two systems is impractical.

In order to obviate this difficulty of parallel operation, a 750-kw. motor-generator set was installed, which constitutes the tie between the 2,300-volt house bus and the main-station bus. In case the exhaust steam available from the house turbine and steam auxiliaries exceeds the amount required for feed-water heating purposes, the speed of the house turbine is decreased by manipulation of the governor. This tends to reduce the frequency on the house bus, and owing to the constant frequency maintained through the motor-generator set, power is fed through it to the house bus, thus reducing the load on the house turbine. The quantity of steam passing through the house turbine to the barometric heater is thus reduced. The motor-generator set is provided with reverse-current relays to prevent the possibility of feeding the current from the house turbine to the main bus. It will be seen

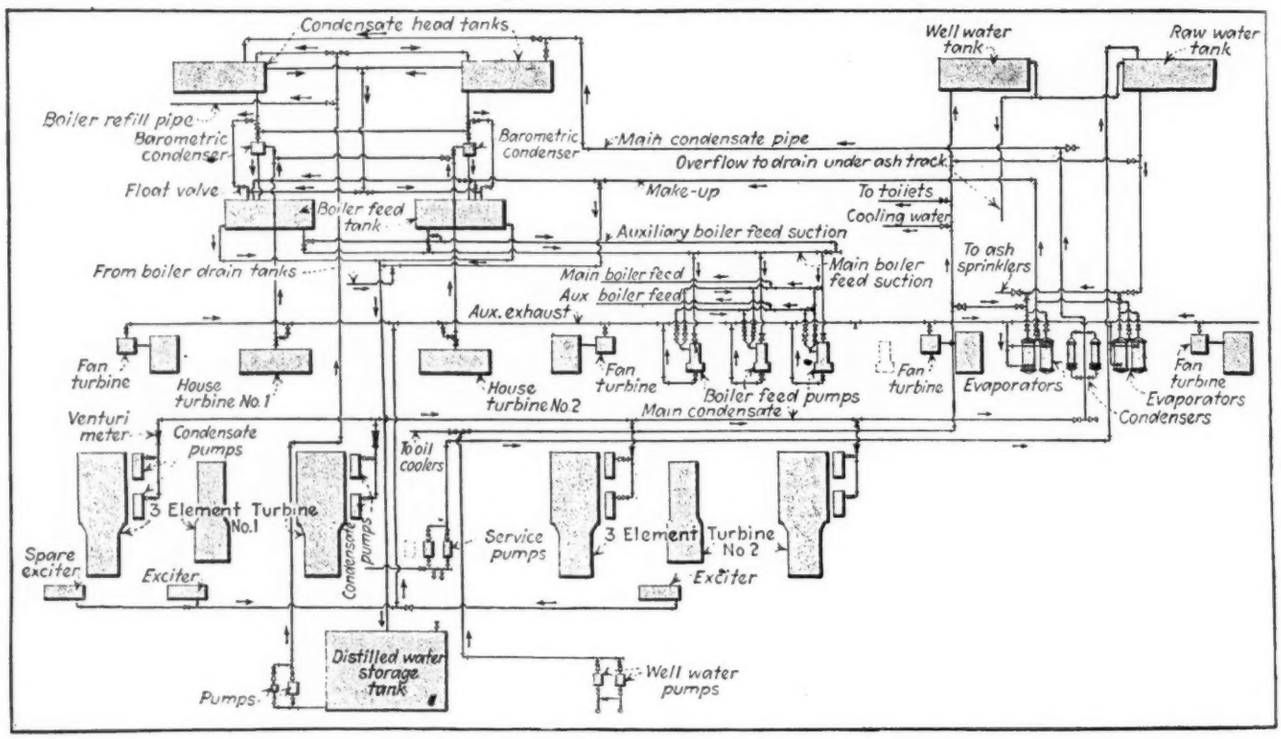


FIG. 3. DIAGRAM OF FEED-WATER AND HEAT-BALANCE MECHANICAL EQUIPMENT

that this system is capable of very close adjustment and permits the maintenance of any desired temperature of feed water. In addition to this the injection water to the barometric condensers is controlled by remote-control valves, to meet the boiler demand.

Fig. 4 shows the system for controlling the water conditions in the barometric condenser. Water-level indicating instruments show the level of the water in all the tanks of the feed-water system. Injection and discharge water and house-turbine exhaust temperatures are shown by indicating thermometers. Control of the injection valves is often necessary on account of change in load and is provided for by Dean control units mounted on the board. The amount of opening the injection valves is indicated by the instruments marked "Bar. Htr. Valve Indic." (Barometric Heater Valve Indicator.)

A thermometer is provided at the main switchboard, which shows the temperature of the water in the boiler-

feed tank. The switchboard operator controls the boiler-feed temperature by a variation of the load on the house turbine and consequent variation of the amount of steam going to the barometric condenser. In case of load fluctuations, the quantity of water flowing into the boiler-feed tank through the barometric condenser may, owing to the time lag in the feed cycle, be in excess of the demand, in which case the barometric-condenser injection valves are partly closed, thus by-passing excess water through the overflow of the head tanks into the storage tank. The purpose of this is to avoid waste of energy in heating a greater quantity of water than is required for boiler feed.

Fig. 2 has been drawn to show the heat distribution in the system at Colfax. For convenience, quantities have been based upon a load of 46,600 kw. on the same unit, as in Fig. 1. With this load and the steam conditions shown, the water rate would be 10.7 lb. per kw.-hr. Starting at the boiler, the heat loss shown is the radiation and friction loss in a fall of pressure from 280 lb. per sq.in. to 260 and a loss of superheat of 5 deg. F. Live-steam leakage which is not recovered has been taken at 5,000 lb. per hour. High-pressure drips which are returned to the system at the boiler-feed tank have also been assumed to be 5,000 lb. per hour. Of the heat contained in this quantity of steam, 840,000 B.t.u. is returned to the boiler-feed tanks, while 5,703,000 B.t.u. is lost in radiation. The total unrecovered water loss in the system has been taken at 15,000 lb., which is made up at the evaporator.

To evaporate this water, 9,000 lb. of the exhaust from the steam-driven auxiliaries is required. The rest of the exhaust steam from the auxiliaries is carried to the barometric condenser, where, with the exhaust from the house turbine, it raises the temperature of the main-unit condensate to 205 deg. F. From the barometric condenser this water flows to the boiler-feed tank, where the distillate from the evaporator and the high- and low-pressure drips are added to it. This makes up the total boiler flow of 580,000 lb. per hour and is measured by two Lea recorders in the boiler-feed tank.

It will be observed that radiation losses in the water piping have not been considered in this diagram, but they are so small that the effect on ultimate result would be inconsiderable. The diagram is drawn to scale, the widths of the various lines being proportionate to the total heat contained in the flow medium. The figures given indicate hourly quantities. This diagram is a fair indication of what may be expected under actual operating conditions in the Colfax power plant.

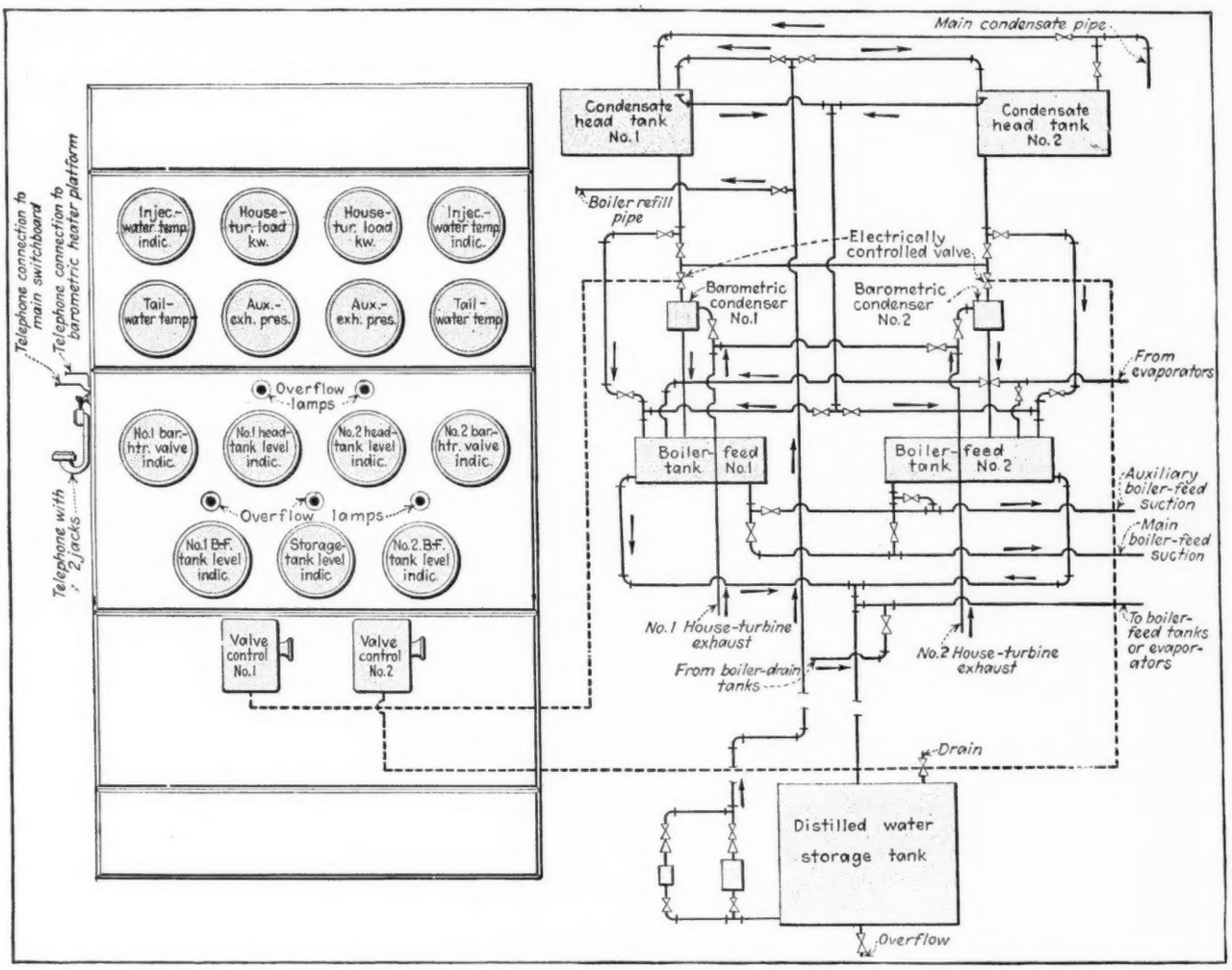


FIG. 4. SYSTEM FOR CONTROLLING THE WATER CONDITIONS IN THE BAROMETRIC CONDENSER

Steam Power Station Design

Main Points Involved in Design of a Modern Station, from Inception of Project. Choice and Arrangement of Equipment for Maximum Return on Investment and Economy of Operation

By FRANK S. CLARK
Mechanical Engineer, Stone & Webster, Boston

THERE are two principal sides to the design of a steam power station, the economical and the mechanical. The former deals with questions affecting primarily the operating results to be obtained, the determination of the characteristics and size of load, the working out of the station heat balance and the selection of proper types and sizes of equipment. The latter deals with arrangement of the equipment and size and type of structures to give maximum ease of operation and maintenance. Combined, they have for their object the production of a station that for the particular case in hand will give reliable service at a minimum cost, all things considered.

Consideration of the source of power required should begin as soon as the discussion of the project itself. With an individual manufacturing concern there are usually two courses open—to generate its own power or to purchase it from a power company. Unless the processes of manufacture demand large amounts of steam, considerations of economy usually decide in favor of purchased power.

> To maintain the desired dependability and efficiency in power-station equipment, it is necessary to place such equipment under a system of definitely scheduled inspection and maintenance. By this means every piece of apparatus is thoroughly inspected at regular intervals and potential causes of trouble are discovered and remedied before damage is done.

Electric power is the chief salable product and source of revenue of companies supplying a community or a district. The processes by which this product is obtained and the materials used in its production therefore are the most vital subjects.

The principal features governing the size and scope of the project are the size of the community or district to be served, the number and type of industries, together with the amount and characteristics of their power requirements, and the lighting and miscellaneous power needs. From these, data curves can be compiled showing the power needs. The curves should show the variations and the shape of curve and in the amount and duration of peak load through different periods of the year. They should cover as long a period as possible, so that an indication of the average rate of growth of load may be obtained. Based on these and modified by possibilities of future increase in load, figures may be arrived at indicating the present size and probable future capacity of station.

Suitable location for a station involves a study of the sites within or adjacent to the district to be supplied. Before any decision is reached, the suitability of the location from an engineering standpoint should be established, and for this reason the opinion of the engineer should be obtained. In making a selection, the location with reference to the delivery of power, the adequacy of condensing-water supply and the accessibility by rail or water for the delivery of fuel should be determined. There should be sufficient room for the development up to the intended ultimate capacity, including space for fuel storage and for outside switching and transforming equipment. In the larger cities these latter two facilities cannot always be provided and compromises must sometimes be made by providing for them at points remote from the station. In some instances sufficient condensing water cannot be obtained within economical transmission distance of the load, and artificial cooling by means of towers or spray ponds must be resorted to. This usually occurs only in the case of stations for industrial plants or for the smaller communities where the loads to be cared for are not large.

While not ordinarily of controlling importance, the subsoil conditions have considerable influence on the type of foundations, the cost of the work and the speed of construction. Determination of these conditions should be carefully made by means of core borings, test pits and test piles. The effect on the cost of the plant of various locations on the property should be considered with the working out of the design.

Usually, the installation up to the ultimate contemplated capacity is made in a number of successive steps covering a period of years. The size of the first step and the time between steps have a decided effect on the design, and location on the site. Each step should not call for investment for construction or equipment not required for that step unless the net expense of the work, if delayed, would be greater. Usually, provision for the work can be made and its execution deferred until actually required.

Flexibility of design is necessary to adapt itself to changes in the art. Rapid advances and radical changes in type and size of equipment have been made and it is logical to assume that this will continue. Detail provision cannot be made for future development, but in general the design should recognize the fact.

It must be remembered, in the selection and installation of equipment, that reliability is the first requisite. There should be no limit to the insuring of continuous service except that placed by the volume of business. Installation of equipment must be made in advance of the time when it will be required as indicated by the rate of growth, and reserve capacity provided to take the load in case of failure of a unit and to permit of the withdrawal of equipment from service at regular intervals for inspection and repair.

Load factor is the starting point in the economics of power-station design and enters into practically every step from the choosing of the site down to the selection of the equipment. "Load factor" is the measure of the

uniformity of production. It is defined as the ratio of the average rate of output to the maximum during a given length of time and indicates the plant's ability to carry the peak load over an appreciable period as distinguished from a momentary swing. Load factor may be applied to a plant as a whole or to any generating unit.

A high load factor means that more investment may be economically made in providing equipment of higher efficiency, the increased fixed charges being more than offset by the saving in operating expense incident to the more nearly continuous use of the equipment.

Heat Balance

Heat balance is an analysis of the thermal processes taking place in a plant from the combustion of the fuel in the furnace to the production of electrical energy. It indicates the distribution of the energy produced by combustion among the different pieces of equipment, accounting for that portion which is usefully employed and for what is thrown away. It is the power-station energy balance-sheet. Its careful study is therefore necessary if the most economical installation is to be made, and many trial balances may be required before the answer is obtained.

Among the first things to fix upon in the working out of a heat balance, and in fact in the design of a station, are the operating steam pressure and temperature. For any given initial temperature theoretically greater thermal efficiency can be obtained with high-pressure saturated steam. Two principal reasons, however, prevent this theoretical efficiency from being realized: First, design and construction of equipment and piping have not yet reached a point to withstand very high-pressure steam generation and second, the theoretical efficiencies of saturated steam cannot be realized owing to losses through condensation, greater friction, etc. It is therefore necessary to effect a compromise by adopting a pressure that is practical from an operating and construction viewpoint and superheating the steam to obtain the maximum feasible temperature range. There are a number of plants today operating at 250 lb. pressure and two or three at over 300 lb. The present state of the art may be said to permit of the economical use of pressures not exceeding 350 lb. and temperatures up to 650 deg. F.

> Of almost equal importance with the actual operation and maintenance is the installation of a system of cost records. Every month a complete report should be made up from these records, giving the operating results obtained and the station costs arranged to show clearly the cost of any phase of operation or maintenance, in total amount and on a unit basis.

Selection of Equipment

Selection of the main units will depend on the character of load, peak load, rate of growth of load and load factor. For the smaller stations the character of the load and shape of load curve influence the selection more than anything else. The sizes and number of units will depend on the relation of peak to base load, duration of the minimum load, relative costs and economies of the units and the spare capacity required. This last should be equal to the capacity of the largest unit in the station. If the system be a small one with a single station and an ordinary light and power load, the first installation would probably consist of two or three units. If two units are installed, they would be of the same capacity, and each would be large enough to carry the peak load. If three units are installed, two would be of the same size, each of capacity sufficient for the day or base load. The third would be of less capacity or large enough to carry the night or minimum load and, in conjunction with one of the larger units, to carry the peak load. If the night or minimum load were sufficiently large, the three might be the same size. As the load grew, the sizes of units in each successive installation would be increased, the size for each step being determined by the day or base load until the load has increased to a point where it equals or exceeds maximum unit capacities or until nothing appreciable is to be gained in station economy by increasing the size of units. Beyond this point, and for the larger stations in which the load exceeds the present maximum unit capacities, the number and sizes will be governed by operating practicability and flexibility.

Advantages of Large Units

Larger units will cost more in total amount but less per kilowatt to install than the smaller ones and will increase the time until the next installation must be made. They require fewer steps for a given development, and the total cost for a given capacity will be less. There will also be some operating economy to be gained on account of greater efficiency of the larger units. The most economical size of installation to make, however, can be determined only by considering the investment and the operating economies in conjunction with the rate of growth of the load.

The economical size of condensing equipment depends on the steam to be condensed, load factor and amount and temperature of condensing water. The temperature of the water varies from month to month and so affects the possible vacuum and the steam consumption of the main unit. How nearly the maximum vacuum possible with the highest water temperature under maximum load is to be approached will depend on the length of time during which these conditions occur. The selection of auxiliaries and their drive is largely dependent on the working out of the station heat balance.

The number and size of boilers and the selection of other boiler-room equipment will depend on the sizes of the main units and the ultimate station capacity. The ratings at which they will be run depends on the shape of the load curves and the station load factor. A high load factor makes it more economical to install more boilers and run them the more nearly at their most efficient rating. A low load factor usually means a shorter peak load, which makes it more economical to install less boiler capacity and increase the ratings over the peak. A comparison of the fixed charges with the cost of operation and maintenance for different numbers of boilers under the conditions existing will indicate the proper number to use.

Whether or not to install economizers is a question of boiler rating, station load factor, heat balance and cost of fuel. Economizers are simply additional heating surface, and the amount it is economical to install depends on initial cost, operating and maintenance costs

and the value of the heat reclaimed. The ratio of economizer surface to boiler surface is based on so proportioning the heating surface between the two as to obtain the maximum heat absorption for a given cost.

The selection of other auxiliary equipment such as pumps, exciters, heaters, etc., depends on reliability and flexibility and on load factor through its effect on heat balance. Failure of auxiliaries may result in as serious an interruption to service as failure in a main unit, therefore there should be sufficient duplication to insure reliability and to give sufficient flexibility.

Duplicate Auxiliaries Desirable

Methods of drive vary from "all steam" to "all electric" with different combinations in between. Comparison of the heat balances of the various combinations will indicate the most economical one. Recent designs for all electric drive contemplate a general duplication of auxiliary equipment with power generated by an auxiliary or "house turbine," and a secondary source of supply from the main unit. This is sometimes combined with bleeding the main unit to obtain part of the steam necessary for the heat balance. This insures reliability and auxiliary power supply through having two independent sources, and the energy in the steam bled from the main unit and that from the house turbine is all returned to the system through the agency of the feed water.

Fuel is the greatest single item of operating expense. Its selection and the means for burning it has, therefore, a decided effect on the station economy. Equipment for burning coal varies with the grade used. The forced-draft stoker is now almost always used in installations of any size. For coking coals of the East underfeed stokers have been generally used. These permit of burning large amounts of coal per square foot of grate per hour with high boiler ratings. They are flexible in operation and permit the rate of combustion to follow closely the variations in load. Recent developments for large installations comprise lengthening the stokers and substitution of clinker grinders for the usual dump plates.

For low-grade coals with high ash content, high volatility and high percentage of sulphur, the forced draft chain-grate stoker is most adaptable. The number of makes of this type is increasing, and they have demonstrated their ability to meet the conditions imposed.

Oil has been used for fuel for a number of years, principally in territories near the oil fields and more recently in localities where there is cheap water transportation. The demand for higher ratings and more efficient operation has led to the adoption of the mechanical atomizing burner. Recent installations, notably at Savannah, Ga., Providence and Pawtucket, R. I., have shown efficiencies and capacities that fulfilled the highest expectations.

Pulverized coal has been attracting attention lately, and several installations are now in successful commercial operation. The preparation of pulverized coal has been pretty thoroughly worked out through its use in the cement industry, but its combustion under boilers is of comparatively recent development. The earlier installations were made under existing boilers whose settings were not designed for pulverized coal, and limitations were thus imposed which precluded the best operating conditions and results being obtained. Several installations designed and proportioned for the burning of pulverized coal are being built and put into operation that give promise of successful and economical operation.

> To obtain maximum economy a steam power station should be operated practically under a condition of continuous test. To do this the performance of the various equipment and of the plant as a whole must be closely followed and instruments should be installed to indicate and record the results obtained and the conditions affecting the operation.

Mechanical Features of Design

The station structure and arrangement of equipment do not in themselves have much effect on station economy. They do, however, have an important effect on the amount of labor required and on the fixed charges. The arrangement of a steam power station naturally divides itself into three parts—the boiler room, the turbine room and the electrical bay or switchhouse.

For simplicity of operation and arrangement the three parts usually are placed side by side, with the turbine room in the middle. Ordinarily, only one division wall separates the boiler and turbine rooms. The electrical bay is sometimes placed with a single division wall between it and the turbine room and sometimes in a separate building or switchhouse. There are a few instances where the electrical bay is at the end of the turbine room and some where the switching equipment is above the turbine room. Local conditions and other special reasons have usually dictated these arrangements.

The number of floors or operating levels in a plant should be kept to a minimum, and so far as possible the different operating levels of adjacent portions should be the same. Thus the condenser floor and ashroom floor levels should be the same, and the boiler room and turbine floor or platform on the same level. Local conditions sometimes make this impossible, as for instance, in stations situated on streams where great differences in levels between high and low water are encountered and where condenser pumps must be placed so as to operate at low water. These conditions create special arrangement of equipment and design of foundations which cost more to erect and force more or less of a compromise with the more desirable arrangements.

Sufficiency of light, both natural and artificial, helps toward good operation and maintenance. It is becoming common practice to provide only a platform four or five feet wide around the main units and leave the rest of the space open to the condenser floor. This permits light to reach all parts of the floor and allows the use of the crane for dismantling and erecting most of the auxiliary equipment.

Boiler-Room Arrangement

Arrangement of the boiler room is usually along one of two lines, either with the firing aisles parallel with or at right angles to the turbine room.

The right-angle arrangement divides the boiler room into a number of different firing aisles, each with its complete installation of coal- and ash-handling equipment, and each row of boilers has its ducts, flues, chimneys, etc., distinct from the other rows. The arrange-

ment splits the boiler-room operation into as many sections as there are aisles.

In the parallel boiler room the boilers are in rows parallel with the turbine room, with usually only one firing aisle unless the boilers are double-stokered. This arrangement utilizes the same coal- and ash-handling system for all the boilers. On the other hand, it makes a longer boiler room, which usually extends beyond the ends of the turbine room unless the turbines are placed lengthwise or, if crosswise, are spaced farther apart than actually required.

Providing easy access by means of stairways and walkways to equipment and other points such as places where valves are located are aids to operation, especially in the boiler room.

Ventilation and Heating

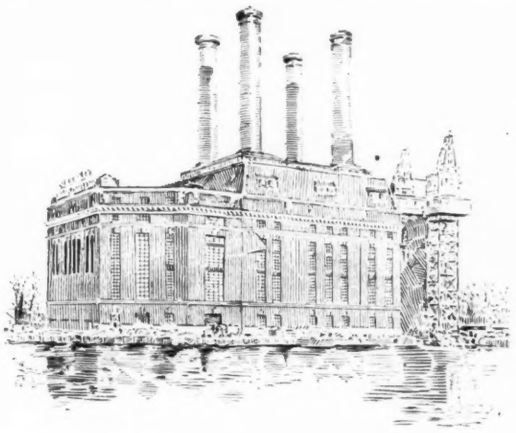
Ventilation and heating are being given more careful thought with each new design. Buses, transformers and switching compartments often require forced ventilation.

Turbine-room ventilation is often combined with the generator air washing and cooling system. In this case the washers usually draw air from the room. In the summer, with the doors and windows open, this draws the outside air into the turbine room and into the generator cooling system. The heated air is either discharged outside the building or into the ashroom, where the forced draft fans can take it. In winter the air is usually discharged into the turbine room.

The ventilation and heating of the turbine room has a direct bearing on roof condensation in winter. In one station now under construction a system is being installed which, it is expected, will prevent roof condensation. The generator air washers are used in the scheme about as previously described, and in addition a separate fan will deliver sufficient washed and warmed air to produce at all times a slight positive pressure in the turbine room. What air leakage there is will therefore be outward and no cold air will be drawn in.

The air required for combustion is many times that which may be discharged by the generators, and in practically all stations this air is drawn from the boiler room and ashroom. The amount is sufficient to change the air in these rooms many times an hour, making a very cold place in winter and exposing pipes to danger from freezing. This condition should be given serious study in new stations with a view to providing means for taking this air from the outside in winter.

Handling of coal and ashes is usually a special problem. Methods of unloading, storing and conveying depend on the way coal is received at the station, the size of the plant and the amount stored. The amount stored depends on the plant output, load factor, the distance from the coal supply and the space available. Some of the largest stations store and reclaim all their coal by means of locomotive cranes. This method has great flexibility and requires less expensive equipment, but is slower and consequently takes more labor than a complete automatic equipment. Bunker storage is either provided over the boiler aisles with individual spouts to the stoker hoppers, or the bunker is located at the ends or centers of the aisles and coal taken from it and conveyed to the stoker hoppers by traveling larries. The larry is coming more and more into general use. It has the advantage of making the whole storage space available for any one boiler instead of only the portion immediately over it, as in the case of individual spouts. It is a reliable piece of equipment and danger of shutdown due to accident is remote. In the larger stations two or more larries are usually provided.



Weighing of Coal Important

Record should be kept of the coal consumed, and for this reason it should be weighed. In some stations coal is weighed as it is being conveyed to the bunkers and a check on the station consumption made at intervals of a week or a month by estimating the amount in the bunkers. This method does not, however, give the close and detailed check that is given by the weigh larry or by individual automatic scales placed in the downspouts to the stoker hoppers.

A simple laboratory for the testing of fuel used and of samples of feed water is usually warranted in the larger stations. This affords means of quickly, accurately and frequently checking up these important items of operation.

Handling of ashes is usually a vexing problem and is often not satisfactorily solved. In the large stations where the facilities permit it, ashes are being dumped from the hoppers direct into railroad cars. This is a very satisfactory and wholesale way of handling the problem. In the smaller stations a motor truck serves the same purpose.

Simplicity of arrangement is an important aid to good operation. Auxiliaries for one main unit should be arranged similar to those of other units. Piping systems, both steam and water, should be as simple as it is possible to make them and still properly perform their intended functions. Duplication of lines to minimize chances of shutdown often defeats its purpose through too great complication.

Automatic Regulation

Devices for the automatic regulation of various equipment and phases of operation are being more and more employed. They vary the conditions and operations of the equipment in accordance with the load. They aid in decreasing the operating cost by practically eliminating manual manipulation, and by adjusting the conditions to the load more closely than is possible with hand regulation. To make them of maximum effect, however, they require intelligence on the part of the operating force and a knowledge of the principles of their operation.

Provision of offices and places for the preparation and storage of records, facilities for the comfort and cleanliness of employees, and of devices for the prevention of accident to equipment and men, all aid toward proper and more efficient operation of the plant, hence they should receive careful attention in laying out the station.

Steam Pipe Sizes

Determination by Pressure Drop Instead of Velocity—Charts for 0 to 1,000,000 Pounds of Steam per Hour at Pressures up to 300 Pounds per Square Inch

BY ALFRED COTTON*

THE old method of determining sizes of steam pipes by assuming arbitrary velocities of the steam, is giving way to the more modern practice of relating the size of pipe to the allowable pressure drop in transmission. In most instances the essential feature is the pressure of the steam at the point where it is to be used, the velocity at which it traveled being of little importance.

One reason for the continued use of the velocity method is the simplicity of the calculations as compared with the tediousness of those based on pressure drop; and the object of this article is to provide means of avoiding these calculations, yet obtaining reliable results.

The formula most frequently used is

$$W = 87\sqrt{\frac{p \times w \times d^5}{L\left(1+\frac{3.6}{d}\right)}} \qquad (1)$$

where W = weight of steam in pounds per minute, p = pressure drop, w = mean density of the steam in pounds per cubic foot, d = bore of pipe in inches, and L = length of pipe in feet.

J. M. Spitzglass (Armour Engineer, 1917) conducted a series of experiments from which he determined reliable coefficients for different sizes of pipe. These coefficients K take the place of

$$87\sqrt{\frac{d^5}{1+\frac{3.6}{d}}}$$

in formula (1). The formula then becomes

$$W = K\sqrt{\frac{p \times w}{L}} \qquad (2)$$

in which W, p, w and L have the same values as in (1). The value of K for nominal pipe sizes is given in the following table:

Nominal Pipe Size	K	Nominal Pipe Size	K
1	45.30	5	3,560
1¼	155	6	5,793
2	313	8	11,800
2½	512	10	21,000
3	933	12	33,000
3½	1,384	14	48,300
4	1,955	15	66,800

Taking W as the weight of steam in pounds per second, Gebhardt gives the value of K as follows:

Nominal Pipe Size	K	Nominal Pipe Size	K
1	0.7	5	60.0
1¼	2.3	6	97.0
2	5.1	8	195.0
2½	8.5	10	350.0
3	15.5	12	550.0
3½	23.0	14	800.0
4	32.5	16	1,100.0

In a number of cases where the necessary observations were made, Gebhardt has applied equation (2) and found it in substantial agreement, and the accompanying charts[1] have been compiled in accordance therewith. The appropriate values of K corresponding to the actual bores of the pipes were obtained by interpolation from the values given in the table, and as the nominal pipe sizes are also given, it is easy to use the charts for commercial pipe. Since most decisions as to suitable pipe sizes are based on the hourly steam consumption, the charts have been prepared on this basis.

PRESSURE DROPS IN MAIN SUPPLY LINES

Pressure drops of 1.5 to 2.5 lb. per 100 ft. are usual in supplying reciprocating engines, while with high-pressure superheated steam supplied to turbines the drop may be from 2 to 4 lb. The graphs are drawn for a length of 100 ft. of straight pipe. As the pressure drop is directly proportional to the length, there is no difficulty in finding the pressure drop for any other length or, more correctly, for any other equivalent length. To find the pressure drop with any exactitude, it is necessary to make allowances in equivalent lengths of pipe for various obstructions, such as the resistance due to the pipe entrance, elbows, valves, etc. The following allowances give fairly close results and may be used with confidence.

Obstruction	Pipe Diameters
Entrance of pipe	60
90 deg. elbow	40
Globe valve	60

Allowances for other obstructions must be estimated. Thus, no allowance need be made for gate valves, and long-radius bends are allowed 5 or 10 diameters, according to their sharpness.

Starting with the intended layout of the steam piping, the obstructions or departures from a straight line are noted and the proper allowances made, and their total expressed in diameters. This total can readily be converted into an equivalent number of feet when the pipe diameter is known. Trials must therefore be made with one or two sizes, since the equivalent length will be different for each size tried. To minimize the labor of this, charts Nos. 6 and 7 have been prepared, so that the equivalent length of any number of diameters of any size of pipe may be quickly found.

HOW TO USE THE CHARTS

To use charts Nos. 6 and 7, enter the lower scale with the number of diameters which have been allowed, proceed vertically to the size of pipe desired, and from the intersection proceed horizontally to the left and read the equivalent number of feet. Add this to the actual length of pipe; and, taking the total pressure drop desired, find the resulting pressure drop per 100 feet.

The following directions show how to use charts Nos. 1 to 4. When the pipe is to carry saturated steam:

1. Enter the lower left-hand scale with the weight of steam per hour.

2. Proceed vertically upward to the curve of pressure at entrance of pipe.

*Chief Research Engineer, Heine Safety Boiler Company.

[1]The charts used in this article are adapted from a series prepared by the writer for the revised edition of "Helios," published by the Heine Safety Boiler Company.

3. From this intersection proceed horizontally to curve of pressure drop.

4. From this intersection proceed vertically downward to the lower right-hand scale and read either actual or standard size of pipe.

While holding intersection 3, proceed horizontally

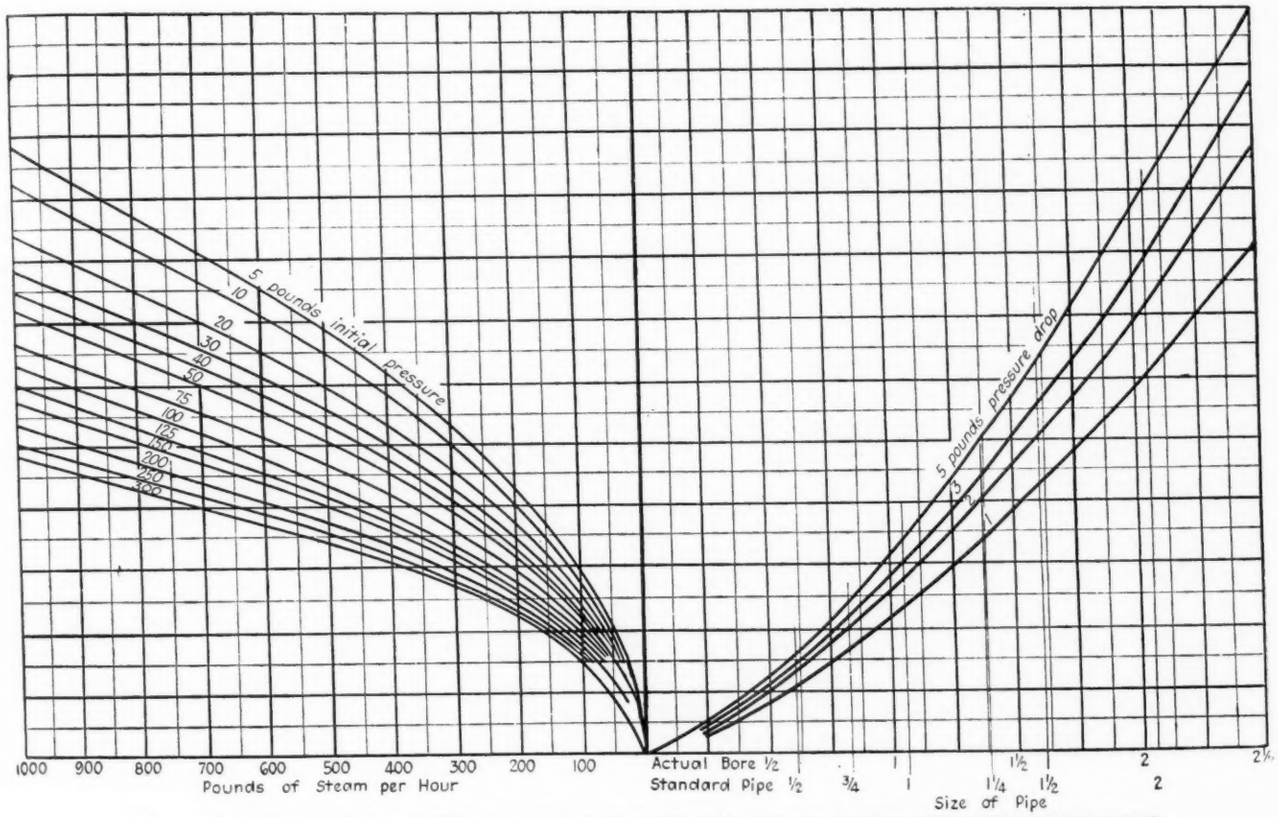


FIG. 1. CHART SHOWING SIZES OF PIPE FOR 0 TO 1,000 LB. OF SATURATED STEAM PER HOUR

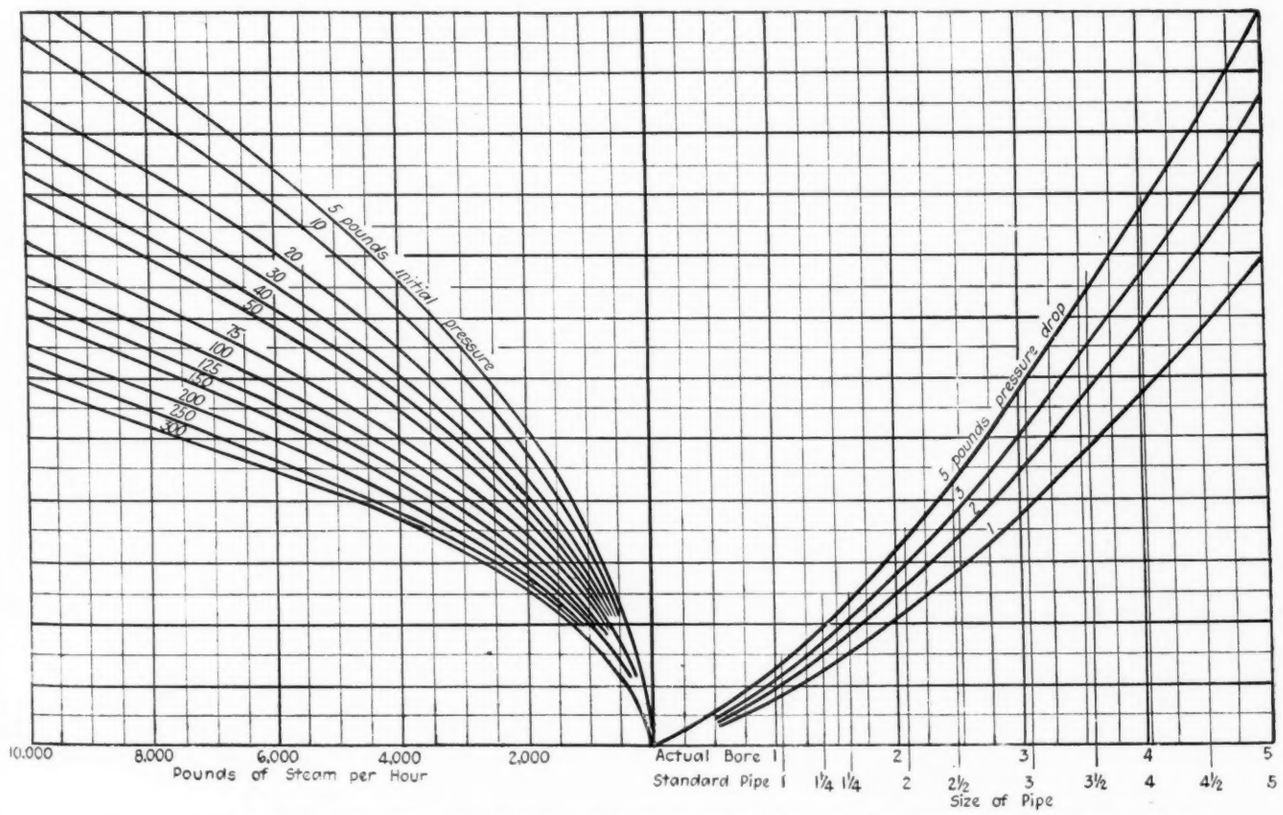


FIG. 2. CHART SHOWING SIZES OF PIPE FOR 1,000 TO 10,000 LB. OF SATURATED STEAM PER HOUR

both right and left, and note the resulting pressure drops for the other pipe sizes.

When carrying superheat enter lower scale of chart 5 with pressure at the pipe entrance, proceed vertically to the curve of the temperature of the steam (not the degrees of superheat) and from this intersection proceed horizontally to the left-hand scale and read the pressure. Use the pressure thus found from chart No. 5 instead of the actual superheated steam pressure in finding the pipe size from the other charts.

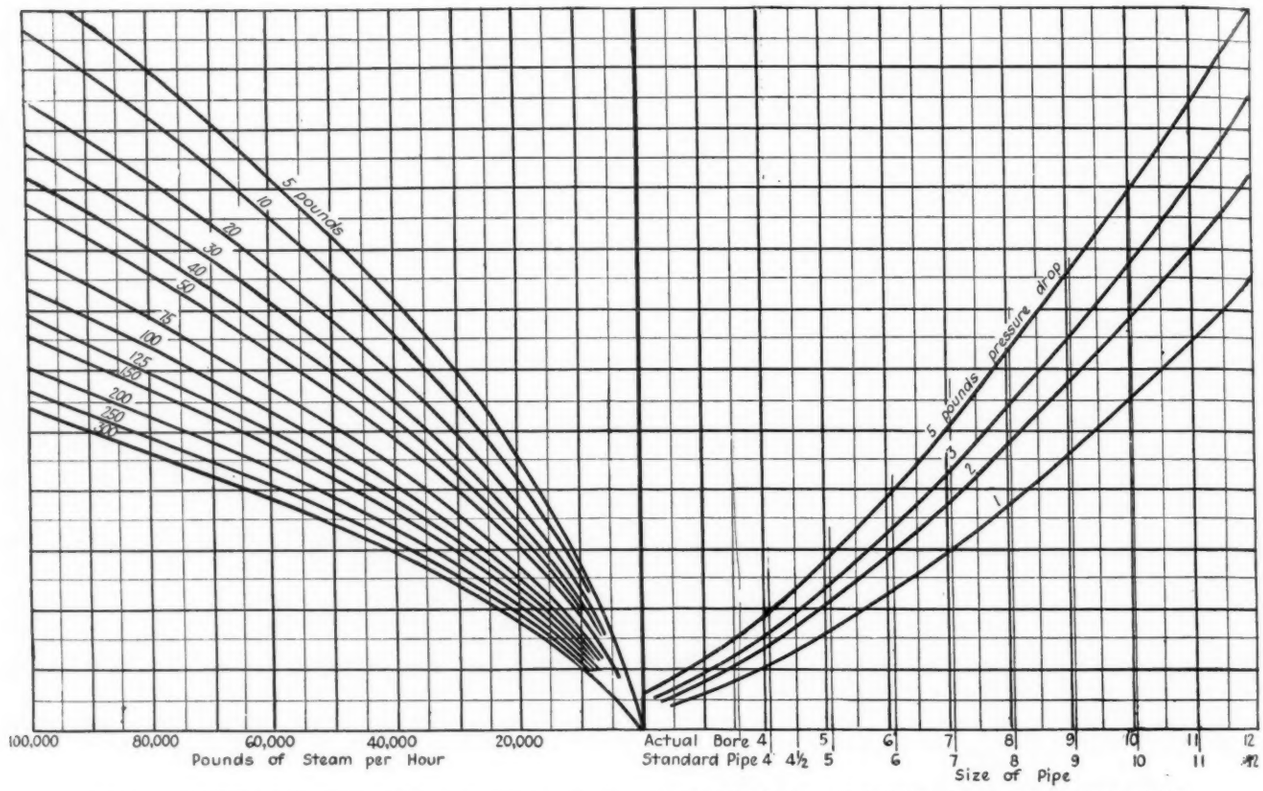


FIG. 3. CHART SHOWING SIZES OF PIPE FOR 10,000 TO 100,000 LB. OF SATURATED STEAM PER HOUR

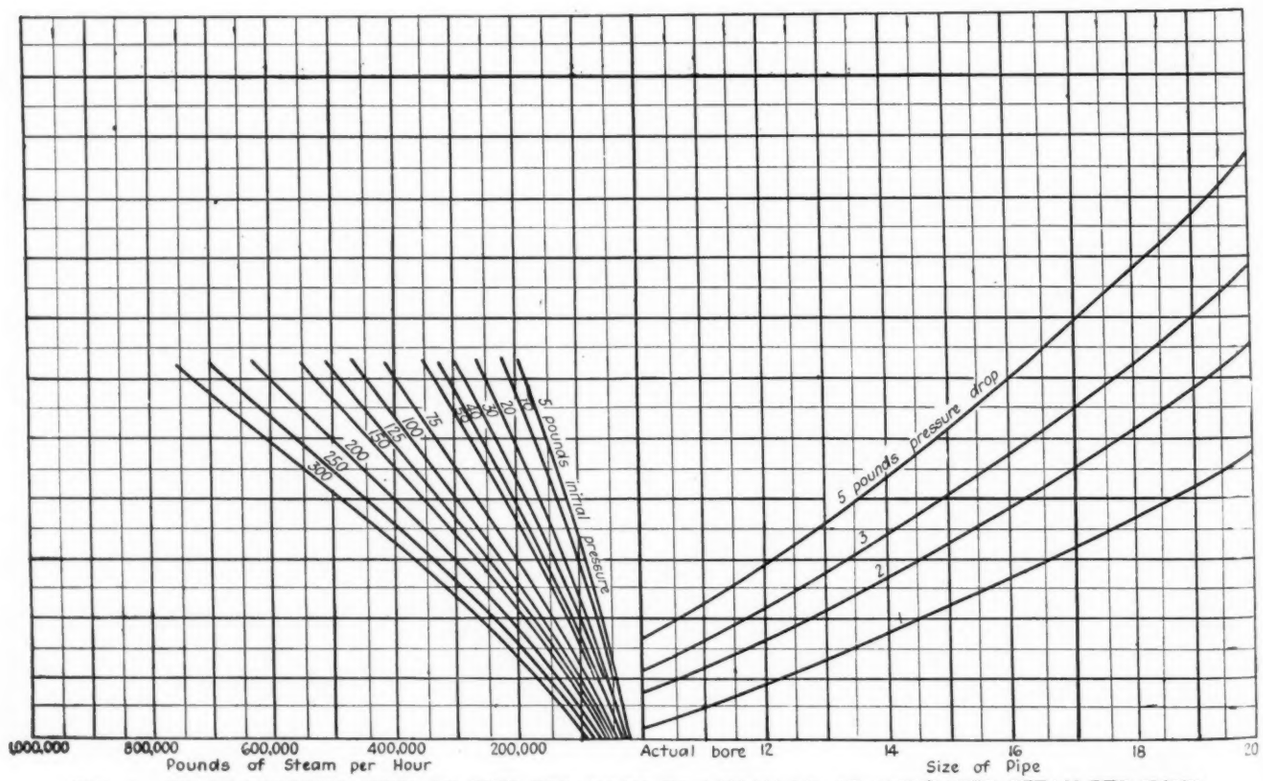


FIG. 4. CHART SHOWING SIZES OF PIPE FOR 100,000 TO 1,000,000 LB. OF SATURATED STEAM PER HOUR

Examination of the formulas will show that they are based on the density of the steam and not on the pressure. But as the density of saturated steam is definitely related to the pressure, curves of pressure have been drawn in preference to those of density, to avoid the necessity of referring to the steam tables. Therefore, chart No. 5 simply finds a pressure where the density of saturated steam is the same as that of the superheated steam in question.

To facilitate understanding the charts, the following examples are offered:

Examples Showing Use of Charts

Example 1—What will be the pressure drop at 15,000, 60,000 and 90,000 lb. of steam per hour under these conditions: 9-in. pipe, 80 ft. long; 3 elbows; 2 globe valves; 150 lb. steam pressure, saturated steam?

Procedure.—From the table of obstructions, derive the following:

	Diameters
Entrance of pipe	60
3 elbows at 40 diameters each	120
2 globe valves at 60 diameters each	120
Total	300

Enter chart No. 7 with 300 diameters, proceed vertically to 9-in. pipe and horizontally read to 225 ft. Add 80 ft. for actual length, which gives a total equivalent length of 305 ft.

Then enter chart No. 3 with 45,000, 60,000 and 90,000 lb. of steam per hour. Proceed vertically with each to intersection with 150 lb. pressure curve, then horizontally to intersection with vertical line of 9-in. pipe and read pressure drops of ¾, 1⅛ and 2½ lb. respectively. These are the pressure drops per 100 ft. and are to be multiplied by 3.05 (hundreds). The pressure drops for this pipe layout at 45,000, 60,000 and 90,000 lb. of steam per hour are 2¼, 3½ and 7½ lb. respectively.

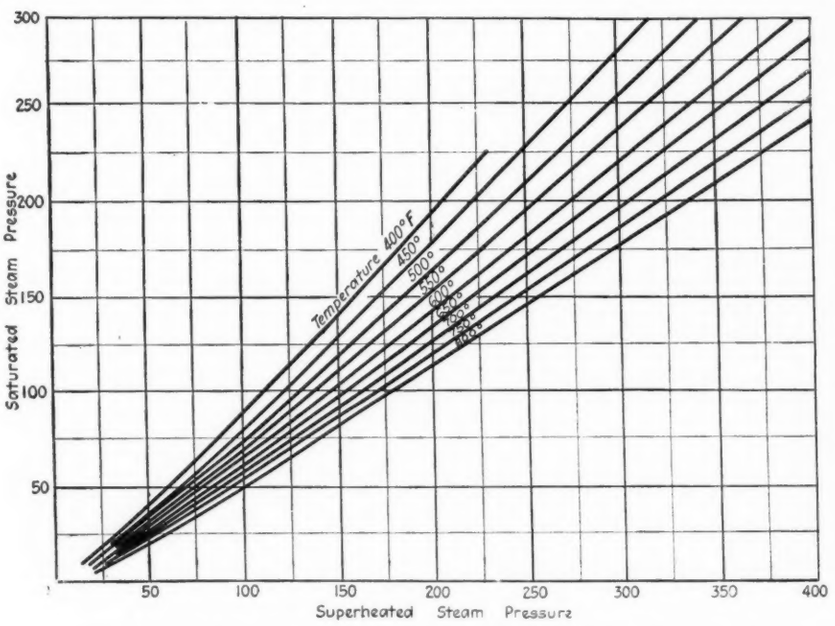


FIG. 5. CHART FOR CONVERTING SUPERHEATED STEAM INTO EQUIVALENT SATURATED STEAM IN FINDING PIPE SIZES

Example 2—What would be the pressure drops with the pipe layout of the last example, if superheaters are installed to give a steam temperature of 500 deg. F.?

Procedure—Enter chart No. 5 with 150 lb. pressure and proceed vertically to the 500-deg. F. curve, then horizontally and read 120 lb. as the pressure of saturated steam of the same density as that of the superheated steam described. Proceed as before with chart No. 3, but intersecting with the 120-lb. curve. The respective pressure drops are ¾, 1⅜ and 3 lb. per 100 ft., and for the layout as described, the total pressure drops are 2¼, 4 and 9 pounds.

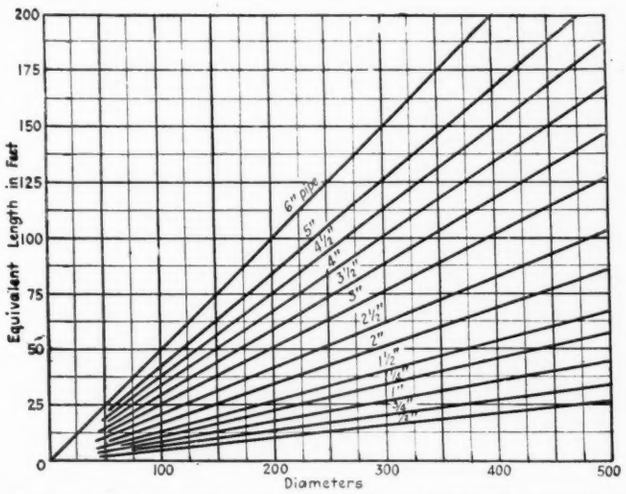


FIG. 6. CHART FOR CONVERTING DIAMETERS OF PIPE INTO EQUIVALENT LENGTH OF PIPE

Example 3—What size pipe is required to convey 210,000 lb. of steam per hour with 5 lb. drop of pressure under these conditions: 120 ft. actual length; 3 elbows; 2 gate valves; 225 lb. steam pressure; 100 deg. F. superheat?

Procedure—From the table of obstructions derive the following:

	Diameters
Entrance of pipe	60
3 elbows at 40 diameters each	120
2 gate valves—no allowance	...
Total	180

From steam tables find the temperature of saturated steam of 225 lb. pressure as 400 deg. F. and add the 100-deg. F. superheat. Then enter chart No. 5 with 225 lb. pressure and proceed to the intersection with 500 deg. F. curve, then horizontally and read 190 lb. as the equivalent pressure of saturated steam to be used.

As we do not yet know the pipe diameter, we cannot find the equivalent length, and so must proceed by trial and error. First, assume that the equivalent length is 200 ft. so that the pressure drop will be 1½ lb. per 100 ft. From chart No. 4 we find that a 14-in. pipe conveys 210,000 lb. of steam per hour with a pressure drop of 1⅜ lb. per 100 ft. Then use chart No. 7 and find that 180 diameters of 14-in. pipe are equal to 210 ft. Add the actual length of 120 ft. and find a total of 330 ft. Then 3.3 times 1⅜ equals 4½ lb. Try 15-in. pipe. Find the equivalent length from chart No. 7 as 225 ft., plus the 120 ft., actual length is 345 ft. From chart

No. 4 read the pressure drop for 15-in. pipe as $\frac{7}{8}$ lb., multiply by 3.45 and find the drop as 4 lb. In the same way the pressure drop for 16-in. pipe is found to be $\frac{5}{8}$ lb., which multiplied by 3.6, gives $2\frac{1}{4}$ lb. pressure drop. These may be tabulated for the particular case under consideration, thus: 14-in. pipe causes $4\frac{1}{2}$ lb. drop; 15-in. pipe causes 3 lb. drop; 16-in. pipe causes $2\frac{1}{4}$ lb. drop, and by comparing the costs of the different sizes, an intelligent choice can be quickly made.

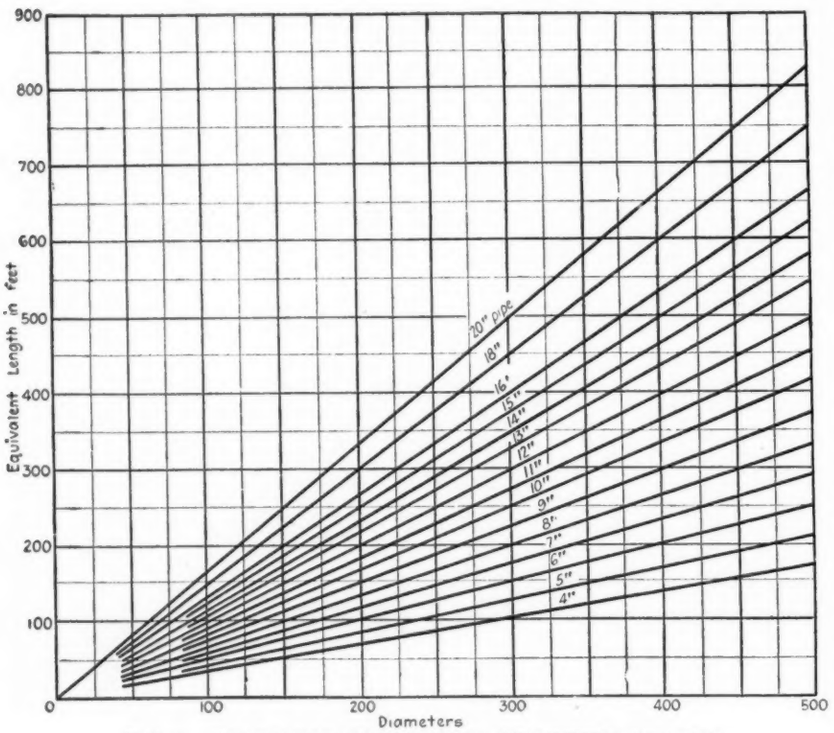


FIG. 7. CHART FOR CONVERTING DIAMETERS OF PIPE INTO EQUIVALENT LENGTH OF PIPE

Effect of Temperature and Specific Gravity on Storage-Battery Operation

By L. W. Webb

The electrolyte in a storage-battery is composed of dilute sulphuric acid and must be made from chemically pure sulphuric acid and pure distilled water. In mixing the two to get the proper specific gravity (usually about 1.250) the acid must be poured into the water and *not the water into the acid.* Add the acid slowly to prevent excessive heating and allow it to cool off before using. Pouring water into the acid might cause acid to be blown up out of mixing tank by the extreme heat generated. Unless the electrolyte is needed in large quantities, it is usually best to purchase it already mixed, and thus be insured of getting the proper quality, as the mixtures should be made only by experienced persons. The conductivity of the electrolyte is greater at about 1.260 sp.gr. and decreases as the specific gravity increases or decreases above this amount. The resistance decreases with increased temperature. The electrolyte should be practically free from all impurities such as iron, platinum, copper, mercury, chlorine, nitrates, etc. Metals cause local action which destroys the active material of the plates and causes it to peel or crack off and fall to the bottom of the jar. The specific gravity of the electrolyte must be maintained the same in each cell, as otherwise these will not discharge uniformly and the battery capacity will be limited to that of the low cells. Hydrometer readings must, therefore, be taken frequently. The quantity of electrolyte in each cell is usually determined by the manufacturer, but if no instructions are available, it is safe to assume that it is sufficient that the electrolyte cover the plates by at least one-half inch. Under no circumstances should the electrolyte be allowed to fall below the top of the plates or expose any of the active material to the atmosphere.

Effects of Temperature on Resistance of Battery and Life of Elements

The maximum temperature a cell should be allowed to attain is 110 deg. F., and when this point is reached, current should be immediately cut off and the cell allowed to cool. The warmer a cell runs, however, the lower becomes its internal resistance and the greater its efficiency, and it is usually desirable, therefore, to run them warm rather than attempt to keep them too cool. Battery rooms are often heated to keep the cell temperatures up for most efficient operation.

As already stated, the capacity of the cell increases with increased temperatures, and vice versa. However, too high temperatures are very injurious and cause excessive evaporation of the electrolyte. It is therefore emphasized that the battery should never be operated above 110 deg. F. A temperature of 90 to 100 deg. F. is usually a very efficient point to work batteries at, and as they are usually rated at 60 deg. F., this gives them a capacity output above the normal rating. It, however, means a greater amount of evaporation to make up for, and unless care is used, the cells will become dry and elements exposed to the air quicker than under normal temperature conditions. However, knowing the danger of running at higher temperatures, the battery really receives more frequent inspections than it would under normal conditions, which is in reality an advantage.

Under no condition should the electrolyte be allowed to freeze. The freezing point of the electrolyte in a fully-charged battery is very low, and there is little danger of its being reached. But when the battery is discharged, the specific gravity of the electrolyte may be so lowered that the freezing point will be above 0 deg. F.

Local action often causes a battery to heat up on open circuit for no apparent reason, and when discovered, it is best to immediately take the elements out and give them a thorough inspection and remove the trouble before replacing in the jar. Batteries that have been discharged too low and left to stand often heat up excessively when subjected to normal charging rates, and the charging current must often be reduced or stopped temporarily. This is due to excess sulphate on plates, which increases the internal resistance and therefore the I^2R heat losses, while the excess sulphate is being absorbed from the plates.

Electric Motors for Conveyor Drive

Mechanical Conveyors Classified—Their Adaptability for Different Services—Operating Speeds, Power Requirements and Operating Characteristics—Motors Employed in This Service, Types of Starter Used and Protective Devices to Guard Against Motor Overload

By GORDON FOX
Electrical Engineer, Freyn Brassert & Co., Chicago

SHORT-DISTANCE transportation of materials is accomplished by intermittently operating devices such as cars, cranes and trucks, or by continuous conveyors. This article deals with the class last named. Mechanical conveyors may be classified into the following general types: Bucket elevators, screw conveyors, scraper conveyors, belt conveyors, flight or pan conveyors, pivoted conveyors and special conveyors.

A bucket conveyor is used commonly for elevating vertically or on an incline, for relatively short distances. This type of conveyor comprises a series of buckets attached to, and spaced at intervals on, a belt or chain mechanism. Belts are used for lighter materials such as flour and grain, while the chain-link type is employed for heavier materials such as coal and stone. The latter class are restricted as to elevation, the entire weight of load and mechanism is carried by the head gear unless the elevator is inclined.

TABLE I. SPEEDS FOR BUCKET ELEVATORS

Material	Speed, Ft. per Min.
Coke	50–100
Coarse stone Lump coal—run-of-mine	90–125
Ashes Lime Cement	150
Crushed stone Sand Gravel	175
Fine coal Grain	200

The proper speed of a centrifugal-delivery bucket elevator is determined largely by the condition of material upon delivery at the head pulley. Light materials, such as grain, are not thrown violently by centrifugal force nor are they damaged by impact with the chute. Belt-type elevators for such materials may be operated at speeds ranging up to 250 to 350 ft. per min. Because of the high speeds possible, comparatively light conveyors are capable of large capacities. Heavy materials cannot be delivered at high speeds. Coal would be broken by such treatment. Elevators for such materials commonly operate at speeds of from 50 to 150 ft. per min. For large capacities at these slower speeds relatively large and heavy elevators are required. The speeds given in Table I represent good practice.

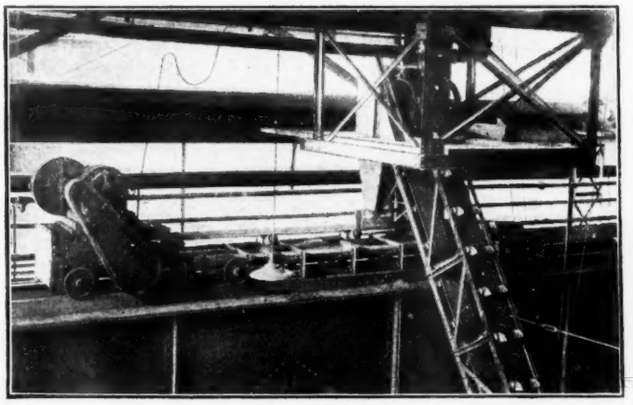


FIG. 1. HEAD GEAR OF INCLINED BUCKET ELEVATOR DISCHARGING INTO SHUTTLE CONVEYOR DRIVEN BY INCLOSED INDUCTION MOTOR THROUGH BACK GEAR AND CHAIN

The trajectory of material leaving a bucket at the top of a centrifugal-delivery bucket elevator depends on the weight and the speed of travel. It will be seen that the elevator speed must be correct in order that the materials may discharge cleanly into its chute. At slow speeds the inclined elevator has an advantage in the matter of delivery.

For driving bucket elevators the power required depends on the design, speed, relative weight, finish of the mechanism, etc. The load involves friction losses plus the power that is required for raising a given weight of material in a given time. A common practice is to allow 50 per cent for losses corresponding to an efficiency of 66 per cent. On this basis the formula $HP. = 0.0015\ WH$ applies, in which W equals the weight of the load elevated in tons per hour and H the height of elevation of the load. Bucket elevators should be driven from the head pulley so that the lifting side will be tight while the empty side may run slack.

Screw conveyors comprise a trough or pipe in which a screw revolves, moving the material forward in so doing. This type of conveyor is usually horizontal or inclined. It is confined largely to fine, light materials such as grain, flour and cement, and is used occasionally in the power plant. This type of conveyor is simple, has a low first cost and is easy to feed and discharge. The fact that it mixes materials as they travel through it is sometimes of advantage. This conveyor, however, is low in efficiency, requiring relatively large driving power. It tends to grind and break material in transit. If the material is at all abrasive, the wear on the conveyor is high.

Screw conveyors should not be unduly long; about 200 ft. is the limit for a 6-in. conveyor and 300 ft. for a 9-in. conveyor. The drive should be located so that the material will be pulled toward the drive end rather than pushed from it. Breakage of a part will then

cause the elevator to clear rather than clog or pile, and the shaft, being in tension, will not tend to buckle. The capacity of a screw conveyor (see Table II) is proportional to the speed, the weight of material and the pitch of the screw. In most commercial conveyors the pitch is equal to the diameter.

The following empirical formulas may be used to determine the power requirements of an average screw conveyor:

Horsepower required for horizontal screw conveyor:

$$HP = \frac{(0.00064\,dR + 0.446\,W)\,L}{1{,}000}$$

Horsepower required for inclined screw conveyor:

$$HP = \frac{(0.00064\,dR + 0.446\,W)\,L + WH}{1{,}000}$$

Where

d = Diameter of conveyor, inches;
R = R.p.m. of screw;
W = Weight of material conveyed, tons per hour;
L = Length of conveyor, feet;
H = Height of elevation, feet.

The scraper conveyor comprises essentially a chain or pair of chains operating over a trough. At intervals along the chain flat steel scrapers are attached at right angles to the chain. These drag through the trough, scraping the material before them. Scraper conveyors

TABLE II. CAPACITY OF TYPICAL SCREW CONVEYORS MATERIAL WEIGHING 50 LB. PER CU.FT.

Screw Diam., In.	R.P.M.	Tons per Hour
4	220	2.26
6	195	6.77
8	175	14.40
10	160	25.70
12	150	41.64
16	130	85.54
24	100	222.00

are relatively simple and cheap, but are not suited for use with abrasive materials. They are inefficient and require rather high driving power. This conveyor is used for handling dirt, ashes, coal and similar materials. The speed of travel ranges from 100 to 200 ft. per min. The speed values listed for bucket elevators may be applied satisfactorily. The power requirements of scraper conveyors may be obtained by the following empirical formulas:

To run conveyor empty:

$$HP. = \frac{0.254\,WL}{1{,}000} \text{ for sliding-shoe flights.}$$

$$HP. = \frac{0.166\,WL}{1{,}000} \text{ for roller flights.}$$

To convey load horizontally, including losses:

$$HP. = \frac{0.954\,WL}{1{,}000} \text{ for sliding-shoe flights.}$$

$$HP. = \frac{0.866\,WL}{1{,}000} \text{ for roller flights.}$$

To convey load up incline, including losses:

$$HP. = \frac{0.954\,WL}{1{,}000} + \frac{WH}{1{,}000} \text{ for sliding-shoe flights.}$$

$$HP. = \frac{0.866\,WL}{1{,}000} + \frac{WH}{1{,}000} \text{ for roller flights.}$$

W = Weight of load in tons per hour;
L = Length of conveyor in feet;
H = Vertical height through which material is raised.

Belt conveyors are in extensive use for handling bulk materials. They are relatively simple, have high carrying capacity and fairly low power consumption. They have a minimum of wearing parts and are adaptable to a range of distances up to about 1,000 ft. They may be loaded and discharged at any point although with some difficulty. They are quiet and positive in operation and

TABLE III. SPEED OF BELT CONVEYORS

Material	Weight per Cu.Ft., Lb.	Belt Speed, Ft. per Min.
Sorting belts		40 to 60
Package conveyors		75 to 125
Coke	30 to 35	200 to 250
Coarse stone	100 to 120	250 to 300
Lump coal	50 to 60	250 to 300
Ashes	45	300
Lime and cement	50 to 60	300
Ore	175	300 to 400
Crushed stone	100 to 120	350 to 400
Sand and gravel	100 to 120	350 to 400
Fine coal	50	400
Grain	25 to 50	400 to 600

ordinarily do not damage material in transit. A magnetic separator pulley may be used for the head pulley and the material discharged over it to separate the tramp iron from the coal or other material handled. Belt conveyors are relatively high in first cost. The belt is subject to damage and replacements are expensive, the belt representing about two-thirds of the cost of the installation.

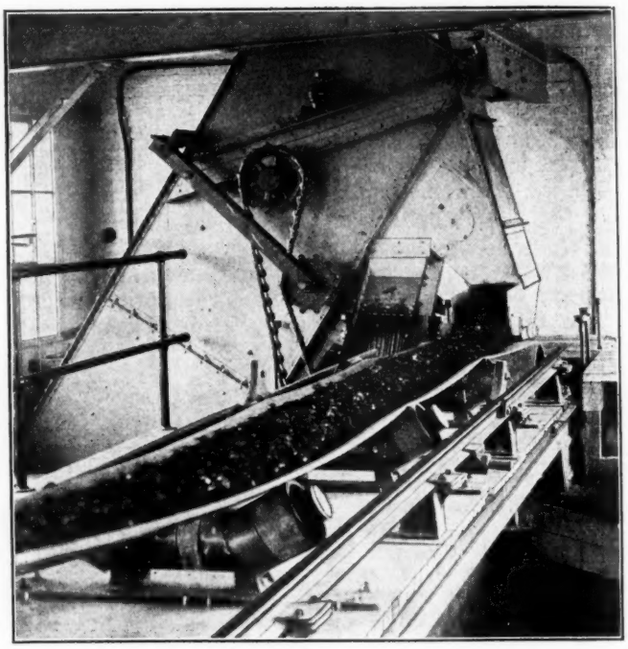


FIG. 2. BELT CONVEYOR AND HEAD OF INCLINED BUCKET ELEVATOR

Belt conveyors may be used on inclines up to 23 deg. from the horizontal, but at this angle there is some tendency for the material to slip back on the belt. They are made in widths of from 12 to 60 in. and operate at

TABLE IV. MAXIMUM ADVISABLE BELT SPEEDS

Belt Width, In.	Maximum Speed Ft. per Min.
14	300
20	350
24	400
30	450
36	500
48	600

speeds ranging from 50 to 800 ft. per min. The speeds given in Table III are representative of good practice.

Wide belts may be operated at higher speeds than narrow belts. If the speeds are too high, the material thins out on the belt. Maximum advisable speeds are given in Table IV.

Where a number of similar belt conveyors are operated in series, one emptying upon another, each successive conveyor should run a little faster than its predecessor. This tends to minimize breakage, The capacity of troughed belt conveyors may be closely approximated by the formula,

$$W = \frac{3.5 \times w^2 \times G}{2{,}000}$$

where

W = Capacity in tons per hour;
w = Belt width in inches;
G = Weight of material per cubic feet in pounds.

The power required by belt conveyors is subject to considerable variation, depending on conditions. The following empirical formulas will closely approximate the correct values in most instances:

To run conveyor empty, power at head pulley,

$$HP. = \frac{KVL}{1{,}000}$$

To convey and elevate load, power at head pulley,

$$HP. = \frac{(KV + 0.071W)L}{1{,}000} + \frac{WH}{1{,}000}$$

where

V = Belt speed, feet per minute;
W = Delivery, tons per hour;
L = Belt length between pulley centers in feet;
H = Lift in feet (for horizontal conveyors $H = O$);
K = Constant having the following values:

Belt Width, in.	14	16	18	20	24	30	36	48
Constant K	0.023	0.032	0.041	0.052	0.061	0.075	0.108	0.145

For each tripper add 1 to 2 hp. according to the width of the belt. The preceding formula gives horsepower values at the head pulley. Where there are belt or gear reductions between this and the motor, the efficiency of this mechanical transmission must be considered and the horsepower values increased 5 to 15 per cent, as necessary. The horsepower values found by the foregoing formula are too low for short conveyors owing to the relatively high friction of the terminal pulleys. increase the power values found by the formula as follows: For conveyors 50 ft. long and under, 20 per cent; 50 to 100 ft., 10 per cent; 100 to 150 ft., 5 per cent.

Power requirements of a belt conveyor may be increased by excess belt tension and by friction of the material at the skirt boards. Too small head pulleys require excess belt tension, which increases the friction load. The use of too few troughing idlers also tends to increase the load.

A belt conveyor should be started empty, if possible, and brought up to full speed before loading. It should not be stopped until fully unloaded, particularly if inclined.

Flight or pan conveyors comprise two strands of roller chain, between and to the links of which are attached flat, beaded or specially shaped slats, or flights. This type of conveyor is similar in action to the belt conveyor, but may be used where the belt conveyor is not adapted, such as for heavy or sharp materials or for inclines greater than 23 deg. Flight conveyors are slower and more cumbersome than belt conveyors. They operate at speeds ranging from 60 to 120 ft. per min. and are difficult to arrange for intermediate unloading. Because of the many joints, the wear is likely to be high. Variations in design and application prevent determination of power requirements from any simple formula. The power required by this type of conveyor will exceed ordinarily that required by a belt conveyor for similar work.

Pivoted bucket conveyors comprise essentially a series of buckets running on tracks provided along the horizontal portions of the run. The buckets are suspended from central pivots so that they remain upright except when inverted by a tripper. The conveyor ordinarily takes the form of a loop with two horizontal and two vertical runs.

As these conveyors carry the material in buckets, they do not tend to damage it. They are, therefore, often used for conveying coal. The fact that they serve both

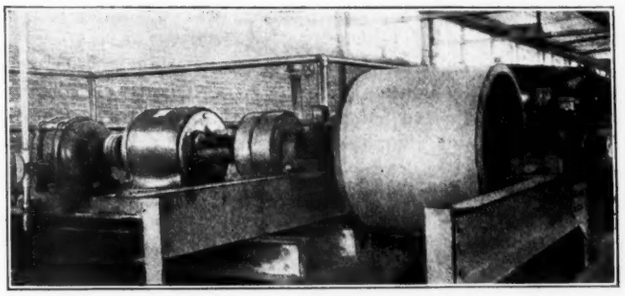


FIG. 3. INDUCTION MOTOR DRIVING HEAD PULLEY OF BELT CONVEYOR USING REDUCTION GEAR UNIT

to elevate and distribute horizontally may be of advantage in avoiding a transfer from an elevating to a distributing means. They may be discharged at any number of tripping points and are fairly efficient. They are normally slow-speed equipments, operating at 25 to 50 ft. per min. The drive is located usually at the head of the down-going strand. The power required depends upon the proportions of the vertical and horizontal sections.

There are many special types of conveyors, such as cooling racks, chain transfers, pig casting strands, conveyors for dipping materials, etc. These are, in general, similar to the standard types in fundamental principles, but each has its special features. It is this class of conveyor particularly, which may require adjustable speed drives.

The great majority of conveyors are continuous-running, constant-speed equipments. Alternating-current motors are therefore well suited for driving them. Direct-current motors are used where such power only is available. The compound-wound motor is preferable in many cases, owing to its higher starting torque and its tendency to protect itself by slowing down under load. Conveyors give essentially a constant torque load, the horsepower increasing with the speed.

Although conveyors are commonly started light, the motor supplied must be capable of starting the conveyor when full of material, since an interruption of power or other trouble may cause the conveyor to stop while loaded, and sometimes the material, such as clay, tends to set while standing, so that high starting torque is required. Cold weather may increase greatly the load incident to starting a conveyor. Many things may increase the friction above normal. For these reasons a motor for conveyor drive should have ample starting torque.

Squirrel-cage motors and wound-rotor motors are both used for conveyor service. The squirrel-cage motor is more commonly employed because of lower cost, simplicity and absence of collectors. The squirrel-cage

motor may lack in starting torque, as it will develop only 110 to 130 per cent torque at about 80 per cent voltage and with five or six times the full-load current inrush. There is considerable argument favoring an oversize squirrel-cage motor rather than a more closely powered wound-rotor motor, inasmuch as a marginal or overload capacity is desirable to meet the exceptional conditions of excess friction, extra-heavy or wet material, etc. The wound-rotor motor is preferable for larger conveyors where the starting demand of the squirrel-cage motor may be a serious consideration.

For small conveyors simple face-plate starters or manual auto-transformer starting compensator are satisfactory. For the large conveyors automatic starters have points of advantage. Conveyors are usually operated by unskilled labor, in whose hands both motor and control may be easily damaged if a conveyor starts hard. Magnetic push-button control with time-element acceleration and overload protection may be recommended in that it will provide maximum safe starting torque, yet protect the motor and also protect the starter from operating too long under severe starting currents. The control should be fully inclosed for protection from dirt, for safety, and to prevent unauthorized tampering.

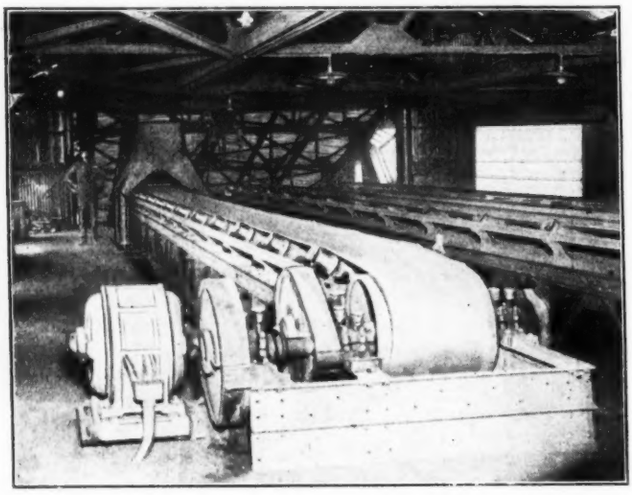


FIG. 1. INDUCTION MOTOR DRIVING HEAD PULLEY OF BELT CONVEYOR THROUGH SPUR-GEAR REDUCTIONS

As conveyor motors are generally located more or less "out of sight," reliable overload protection is more necessary than for motors under regular observation. Instantaneous trip circuit breakers or overload relays are of advantage as a protection to the conveyor itself in case foreign material or some other mishap causes a jam. The best arrangement in some cases may comprise two overload relays, one set high to protect against too severe starting peaks, the other set low enough to protect the motor and conveyor, the latter being in circuit only while running. A reliable inverse-time-element overload relay may serve a like purpose, but a relay that will permit the starting peaks of a squirrel-cage induction motor may not trip quickly enough to protect a conveyor from damage.

Sometimes it is desirable to be able to adjust the speed of a conveyor. The adjustable-speed direct-current motor is then the best-suited drive. Armature- or rotor-resistance control is wasteful and is feasible only where a comparatively small range is desired or where operation at reduced speed is for short intervals only.

If an elevating or inclined conveyor is stopped while loaded, the weight of the material may tend to drive the conveyor backward. If this is objectionable, it may be overcome by the use of some form of ratchet or stop applied to the conveyor drive. Solenoid brakes are seldom used for this purpose.

When a conveyor feeds a process machine or feeds another conveyor, it is usually desirable that the feeding conveyor stop when the machine or feed conveyor stops, in order to prevent a piling up of material. Interlocking is commonly practiced by opening a pilot circuit or trip circuit of the control of the feeding conveyor when the fed machine is shut down. The machines must then be started again in proper sequence.

Conveyors by nature cover considerable space. It is often desirable to start, or more particularly to stop, the conveyor from a plurality of stations along its run. Magnetic starters may be easily applied for both starting and stopping from several points. The remote-stop feature may be obtained with most any control through use of push buttons interrupting a pilot or no-voltage trip circuit of the starter.

Motors driving conveyors are of moderate speeds, driving through one or more gear reductions or by chain or belt from the motor to the first reduction shaft. Belt drive has the advantage of relieving the motor from shocks and vibration, which may be a considerable factor. Conveyors in general do not contribute to cleanliness. The motor should be located where it will be as free as possible from droppings and dust. Total or partial enclosure is frequently desirable, particularly if direct-current motors are used. Dirt will damage insulation on any motor, and it affects ventilation nearly as much as inclosing the motor.

Lubrication of Reduction Gears

The use of reduction gears introduces a new problem in the lubrication system. These gears have excessively high tooth pressures running from 500 to 750 lb. per sq.in., and in order to run smoothly and without wear should be lubricated. Too low a viscosity oil will not withstand these high pressures and will not prevent wear on the tooth surface. In any gear there is a slight slipping in the meshing action and the lubricant should prevent or reduce the degree of metallic contact of these surfaces.

It is generally considered desirable to supply a different lubricant to the gears from that supplied to the bearings, but in many cases this is found impractical and the gears are supplied from the same lubrication system as the bearings. This means that the oil used in the general system must be of sufficient viscosity at the temperature at which it is supplied to the gears to withstand the high tooth pressures and prevent wear. Oils of 300 to 500 seconds viscosity at 100 deg. F. have been found to operate quite satisfactorily on the gears. On very slow running gears which normally have higher tooth pressures an oil with a viscosity of even higher than 500 seconds is often recommended.—*Lubrication.*

To the employee an accident means physical pain and loss of time and often privation in his family. To the employer it means decreased production, publicity of an unwelcome kind, and the payment of compensation claims. Cut down the accidents and cut out their consequences. It pays at both ends.—*The Travelers Standard.*

Dodge Brothers Modern Power Plant

By THOMAS WILSON

PRODUCTION, incessant and ever increasing, has been the creed of operation for the modern automobile plant. Essential to this production is power, a continuous supply of steam and electrical energy, unlimited to the extent that output never is to be curtailed. This means duplication to guard against breakdown and reserve capacity to care for any emergency that may arise. With an output of 600 cars a day and with the intention of increasing gradually the deliveries to 1,000 cars, Dodge Brothers felt the need of an efficient, reliable power plant. Increased by the use of electric ovens for japanning and drying of the steel car bodies, the electrical load was approaching 15,000 kw. and there was an additional continuous demand for 250,000 lb. of steam. The character of this load for a day of normal production is shown by the curve in Fig. 9. The load factor for such a day was 75 per cent and the average for the year 55 per cent. A plant of sufficient capacity to carry this load was desired and of such type that its output could be readily increased. Efficiency was to be a factor, but continuous, reliable service was the first requirement, as even temporary curtailment of production would mean much more to the company in dollars and cents than the comparatively small additional investment required to insure such service. To meet the requirements, a plant of the unit type was designed; that is, a turbo-generator with its boilers and auxiliaries comprise a plant unit capable in itself of being operated independently of any other unit. The original layout proposed the installation of four units of 12,500 kva. each, making an installed capacity of 50,000 kva. Eight boilers, two per unit, each having 12,870 sq.ft. of steam-making surface, were to serve the generators and supply the steam needed for other services. Temporarily, one of these services was to supply steam to the hammers in the forge shop, but it is the intention to move this department, so that eventually the boilers principally will care for the electrical load, exhaust steam from one of the turbine units being used for heating. At present, exhaust steam from the hammers supplies this service and during the summer goes to a low-pressure turbine in the older plant of the company. While construction work was in progress on the basis outlined, the depression in the industry altered conditions, so that for the time being it was not considered advisable to install the complete plant, and instead of the initial turbine unit being 12,500 kva. two 4,000-kw. machines have been installed. The boiler-house foundations have been put in for four units; the parts of the superstructure now nearing completion will accommodate six boilers and the turbine room and switchhouse one unit. Temporary walls at one end of the plant allow for expansion and the addition of units as they are needed.

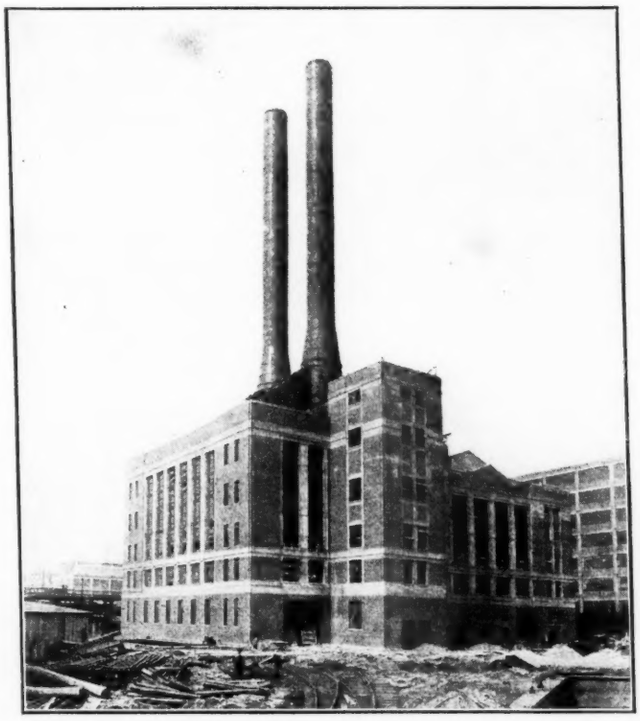
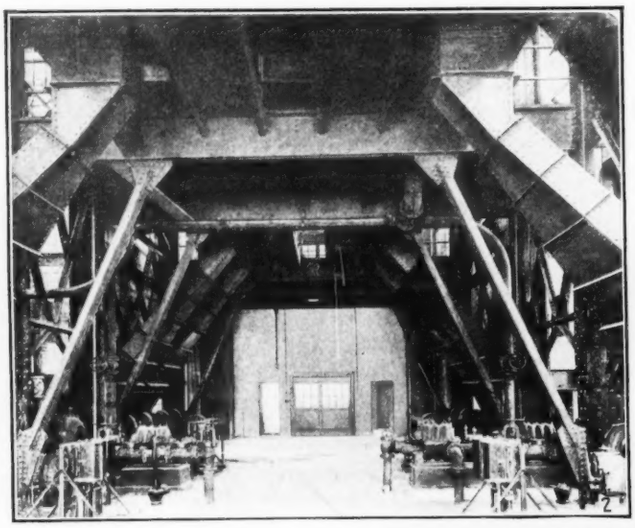
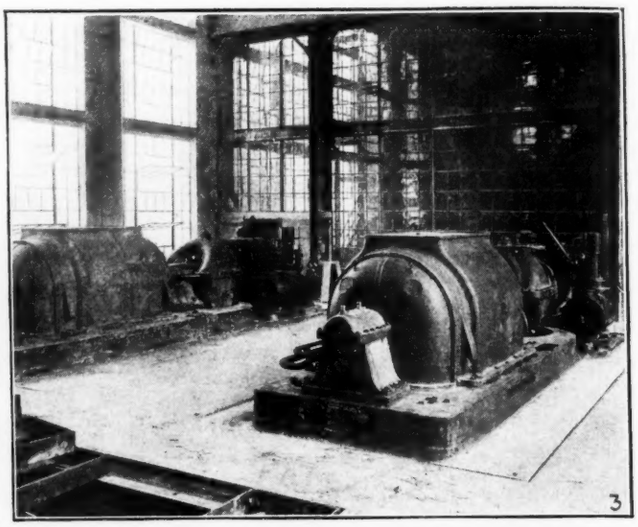


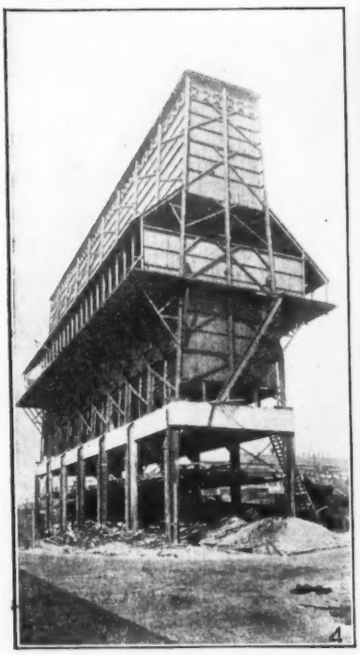
FIG. 1. NEW POWER PLANT AT THE DODGE BROTHERS WORKS

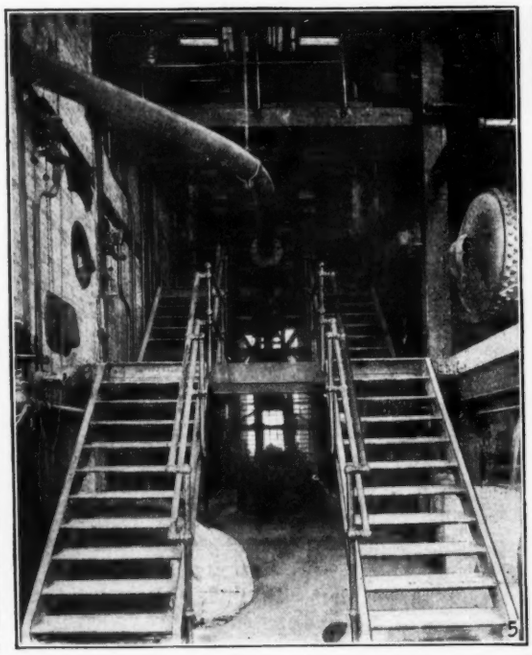
In choosing the site for the power plant, there was very little space available on the land occupied by the factory buildings. After providing for future extension of manufacturing departments, there was left a small area east of the present assembly building that was available for the power plant. If little coal storage were provided at the plant other than that afforded by the overhead bunker, it was found that it would be possible to locate the plant on this site by building the turbine house and switchhouse on the land available and the boiler house over the railroad track serving the assembling

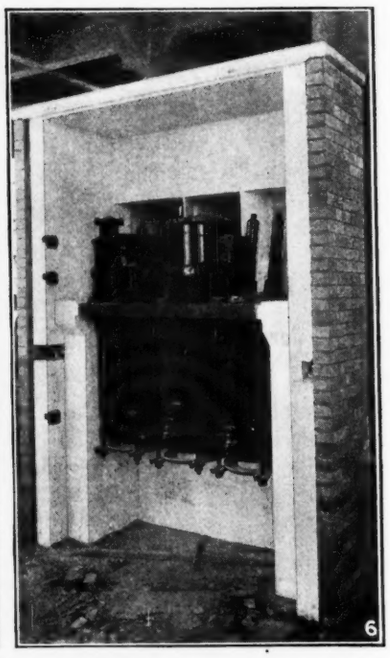
Reliable and continuous service was the watchword controlling the design of this plant, which is arranged on the unit plan and is to have an ultimate capacity of nearly 50,000 kva. Among the numerous interesting features in the boiler room are the boiler setting, the provisions for coal and ash handling, the boiler-feed system, the high-pressure piping and the vertical layout of the equipment. The turbines are mounted on heavy structural steel foundations. The electrical system is special and designed for maximum protection. A combined natural- and induced-draft cooling tower, the largest of its type, is mounted thirty-three feet above grade over a loading platform. To maintain the heat balance a house turbine is to operate in conjunction with a synchronous-motor-generator set.

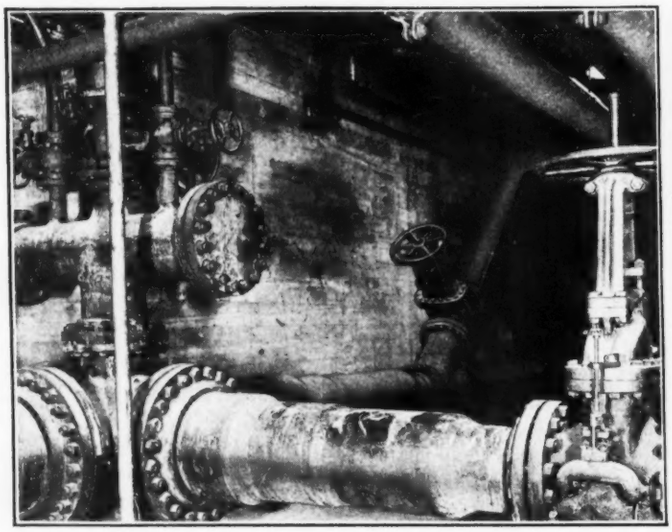


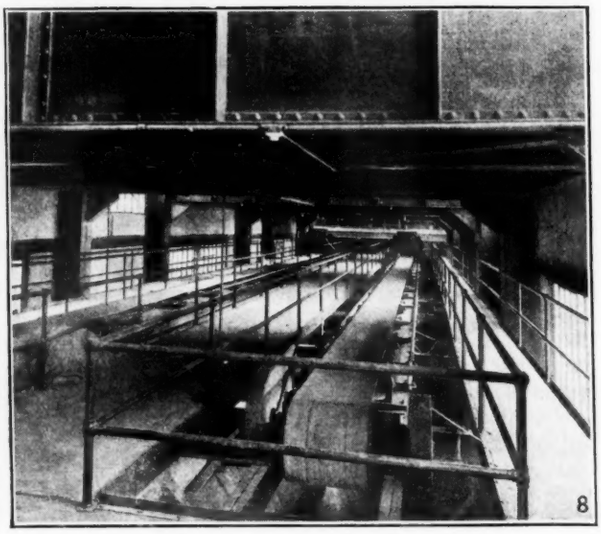












FIGS. 2 TO 8. VIEWS OF SOME OF THE EQUIPMENT IN THE NEW DODGE BROTHERS POWER PLANT

Fig. 2—The motor-driven boiler-feed pumps are placed on the boiler-room level, also the motor control. Fig. 3.—Two 4,000-kw. turbo-generator units. Fig. 4.—This cooling tower is the largest of its type in the world. Fig. 5.—Instead of ladders, stairways give access to all levels of the boilers. Fig. 6.—One of the generator switch compartments. Fig. 7.—This cross-fitting and manifold serves as a steam header. Fig. 8.—Twin belt conveyors over bunker, self-propelling trippers are at the far end.

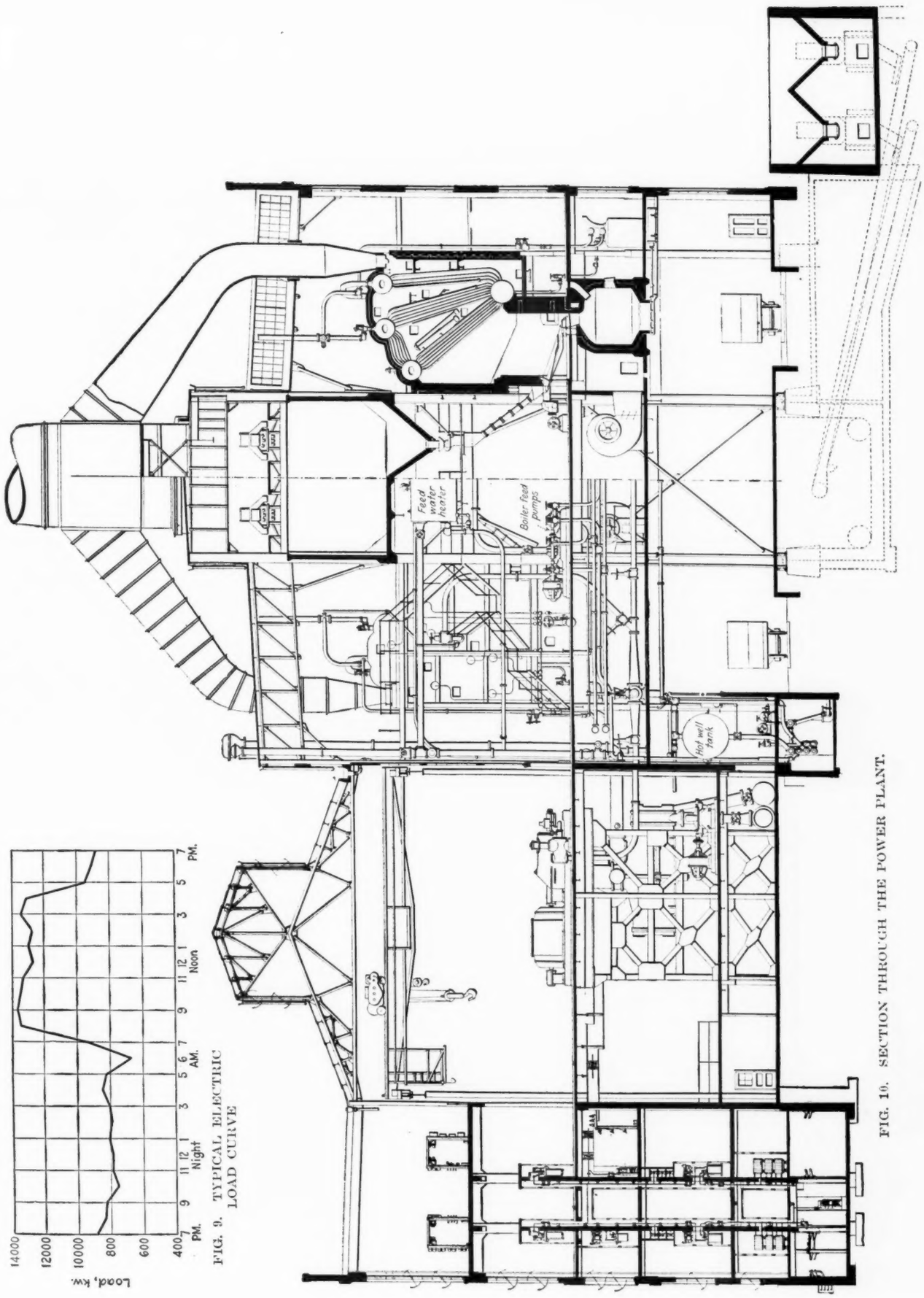


FIG. 10. SECTION THROUGH THE POWER PLANT.

FIG. 9. TYPICAL ELECTRIC LOAD CURVE

and shipping departments. The cooling tower for conserving the condenser circulating water is located nearby, but it was necessary to erect it 33 ft. above grade over one of the loading platforms. Owing to the restricted space the power-plant structure was made higher than the average industrial plant.

The present three-unit boiler house is 131 ft. 3 in. long by 100 ft. wide; for the fourth unit the length will be increased by 35 ft. The upper part is occupied by the boiler room, the floor of which is 35 ft. above grade to permit railway cars to pass underneath. Above the firing aisle is a balcony carrying the coal scales and feed-water heaters, and higher up is the coal crane. At the end of the boiler house is a tower containing the coal-handling bucket elevators, the combination freight and passenger platform elevator, the main stairway connecting the various elevations, and the toilet and locker rooms for the use of employees of the plant.

Only the first generating unit has been restricted to 8,000 kw. and this is divided into two machines. The remaining three machines, when installed, will have a rating of 10,000 kw. at 80 per cent power factor (12,500-kva.) so that the relative proportions of turbine and boilers will then be more nearly balanced. At its normal rating each boiler will deliver 44,500 lb.

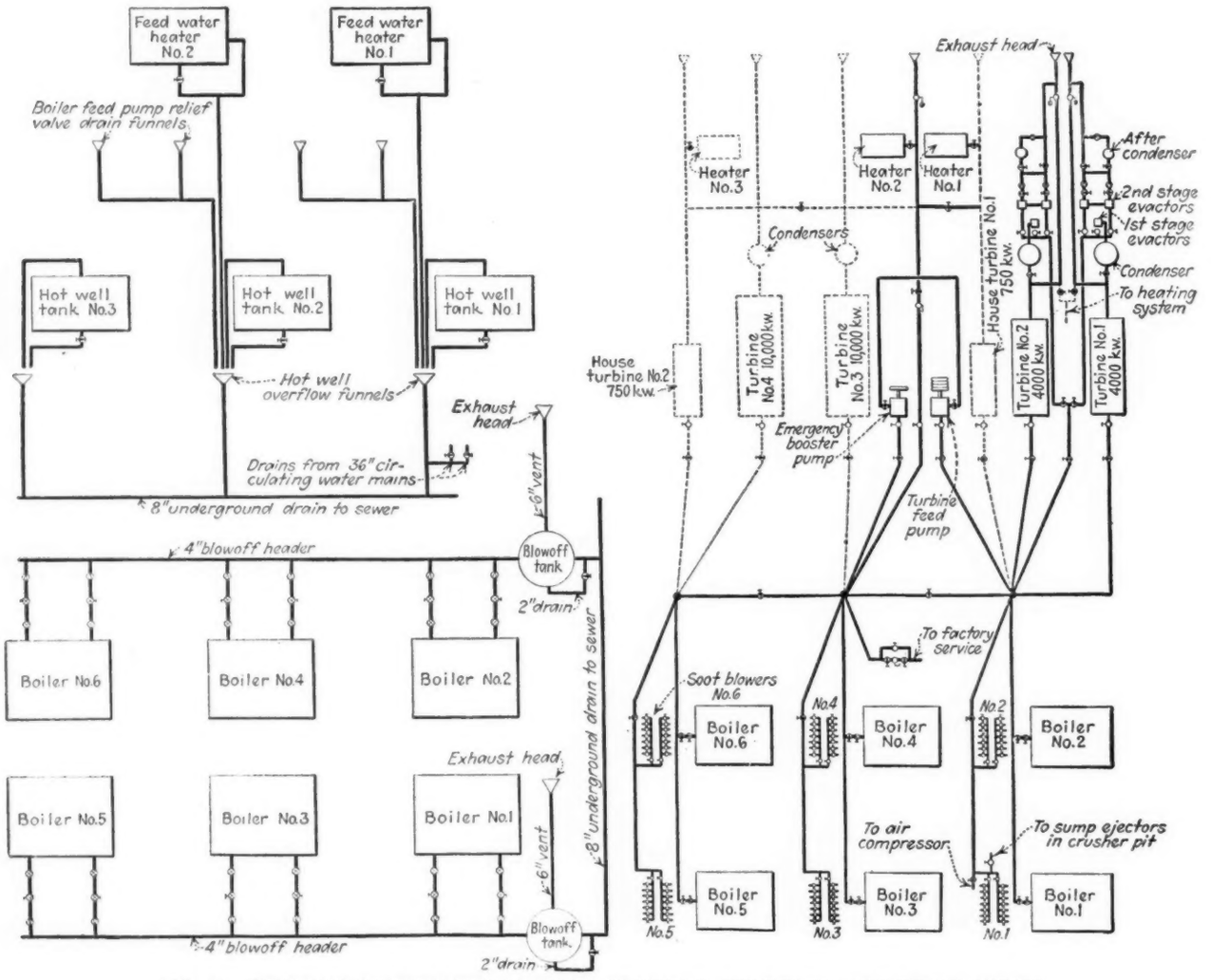


FIG. 11. DIAGRAM OF THE STEAM PIPING, BLOWOFF, OVERFLOW AND DRAIN PIPING

bunker. Thirteen feet below the boiler-room floor is the fan-room floor on which are located the forced-draft fans and the ash hoppers. On the turbine-room side is the pumproom, with a pipe gallery below it.

The turbine house is 60 ft. wide, and the ultimate length will be 166 ft. 3 in. The completed portion measures 54 ft. 6 in., which is sufficient to house one unit. The elevation of the turbine-room floor is the same as that of the boiler-room floor. Below is the condenser floor, and at grade level are located the generator air washers, intake and discharge lines connecting the condensers and cooling tower, and the railroad track terminating at the hatchway under the turbine-room

of steam per hour, and the guaranteed maximum capacity is approximately 130,000 lb. It is the intention to operate the boilers normally at 200 per cent of rating and to push them harder to carry the peaks. Each boiler is served by an underfeed stoker with an individual motor drive, a forced-draft fan and a boiler-feed pump per unit. The two boilers forming the unit discharge the products of combustion through overhead smoke flues with easy bends into opposite sides of a self-supporting steel stack. The latter is supported on the central columns of the building structure, which also give support to the bunker and the boiler drums and setting.

At the top the stack is 13 ft. in diameter and at the base, 18 ft. The height is 170 ft., or 235 ft. above the boiler-room floor. At the boiler outlet the smoke flue has a sectional area of 65 sq.ft., which for structural reasons enlarges to 95 sq.ft at the opening into the stack. The furnace volume approximates 2,800 cu.ft. Reducing these dimensions to the basis of 100 sq.ft. of steam-making surface gives a stack area of 0.517 sq.ft., a flue area of 0.505 sq.ft. and a furnace volume of 21.7 cu. ft. At the normal operation of 200 per cent rating, each boiler evaporates, in round numbers, 89,000 lb. of steam per hour, requiring about 11,000 lb. of coal. On this basis the furnace volume will reduce to ½ cu.ft. per pound of coal burned per hour. The operating pressure is 225 lb. gage, although the safety heat-resisting qualities. An inspection door is provided at the side of the hopper, and an entrance for the soot from the rear pass of the boiler (see Fig. 10). In addition to receiving the ash, the hopper has another function. When necessary, it is proposed to remove the boiler tubes from the bottom of the boiler, through the dump opening and ash gates at the bottom of hopper.

An underfeed stoker with twelve extra-long retorts serves each boiler. It is driven by a 15-hp. compound-wound direct-current motor through a silent chain drive. Through both field and armature control the speed of the motors may be varied from 200 to 1,200 r.p.m., giving a wide range to meet the variations in the steam load. Each motor is mounted in front of its individual stoker, and for the present the controller,

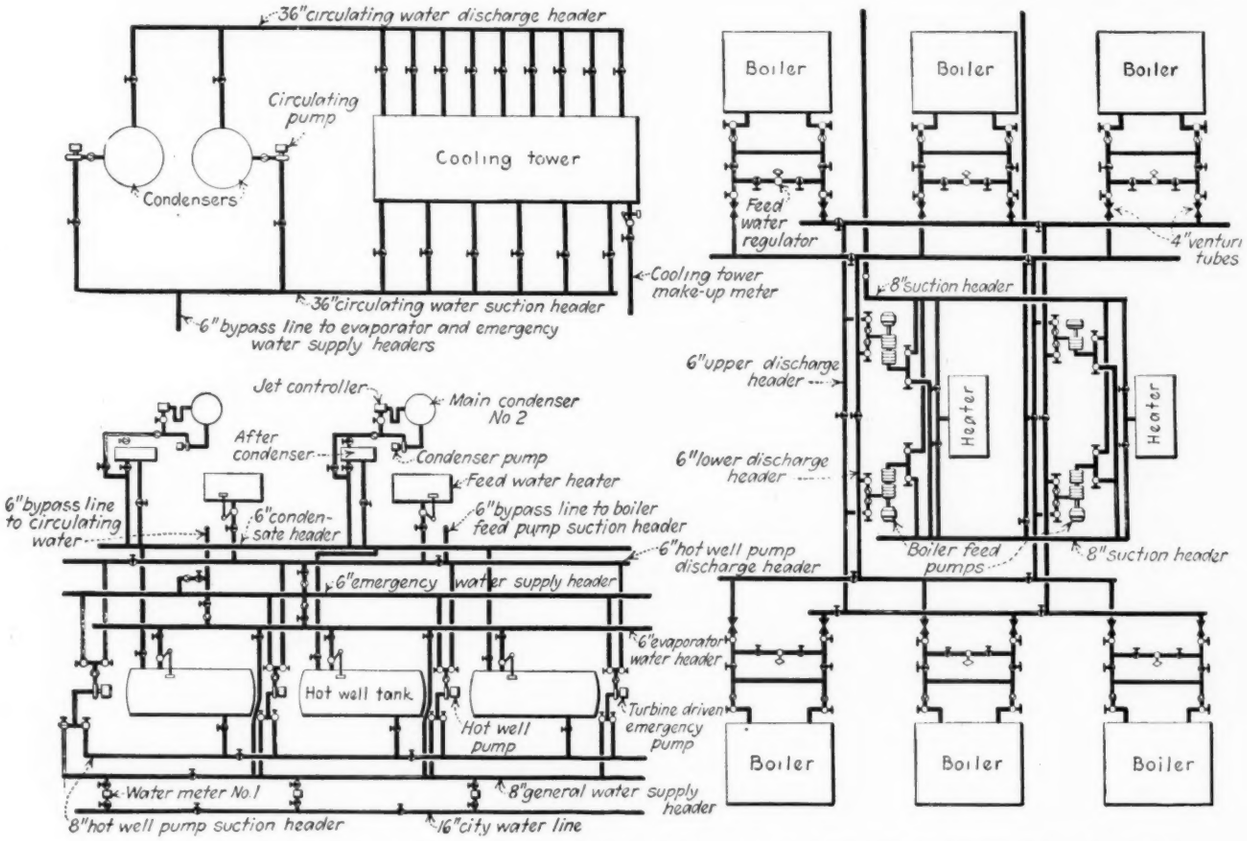


FIG. 12. DIAGRAMMATIC LAYOUT OF FEED-WATER, HOTWELL AND CIRCULATING-WATER PIPING

valves are set at 250 lb. Between the first and second banks of tubes sufficient superheating surface has been provided to give a superheat of 100 deg., and space has been left for more surface to give an additional 100 deg. should it be desired. Space has been provided for economizers and induced-draft fans should it be decided to install them later.

One of the notable features of the boiler is the large ash hopper employed. It is 10 ft. wide, 9 ft. 3 in. deep and 25 ft. long, which gives it a capacity of about 2,300 cu.ft. In this volume over 100,000 lb. of ashes, equivalent to more than a four-days' run, may be stored. The outlet of the hopper passes through the fanroom floor so that the ashes may be discharged directly into railway cars through three 5 x 5 ft. gates operated by compressed-air cylinders.

The ash-hopper walls are of 9 in. of concrete lined with 9 in. of paving brick having special abrasive and which is of the street-car type, is placed near it. Later on it is the intention to mount this control on an instrument panel now being designed for each boiler.

For forced draft, each boiler has its individual fan, which is guaranteed to deliver 54,200 cu.ft. of air per minute against a static pressure of 7½ in. The fan is driven by a 100-hp., 220-volt direct-current motor and, by control similar to that of the stoker motors, the speed may be varied from 325 to 950 r.p.m. Discharge from the fan passes into a large windbox under the stoker. Cooling air from the turbo-generators has access to the fanroom, so that the stoker air is preheated to a certain extent by waste heat.

Each boiler is served by a fourteen-element soot blower. The blowoff valves are located conveniently in the offset back of the bridge wall. The boiler room is provided with stairways giving access to all points desirable.

For the most part the piping is congregated in the fanroom beneath the aisles between the boilers. Little of it, except the necessary connections to the boilers, is visible from the boiler-room floor. The high-pressure piping, designed for 250-lb. pressure, is of steel, with steel fittings and steel body valves having monel trim and stem. From the opposing boilers forming the unit, 10-in. leaders swing down into the fanroom and unite through a Y-fitting. The line then continues through an increaser fitting to a special 20-in. cast-steel cross, with a manifold on top from which the steam supply for auxiliaries, process work, steam hammers or for any other work may be taken out. On the side of the cross opposite to the steam entrance, the connection for the main turbine is made through a fitting reducing from 30-in. belt conveyors rising on an incline of 15 deg. to continuous bucket elevators having an elevation of 105 ft. between centers. Each of the two bucket conveyors may deliver to either one of two 175-ft., 24-in. belt conveyors running the full length of the overhead storage bunker. Each is provided with a self-propelling tripper. The capacity of each is 75 tons per hour.

All motors driving the conveying and crushing equipment are of the induction type and a push-button interlocking system of control has been arranged so that the motors may be started and stopped progressively.

Coal for each boiler will be delivered to two stationary scales which discharge to structural steel spouts built up of plates and angles and flaring out at the stoker hopper to a width of 8 ft. 8 in. The coal scales

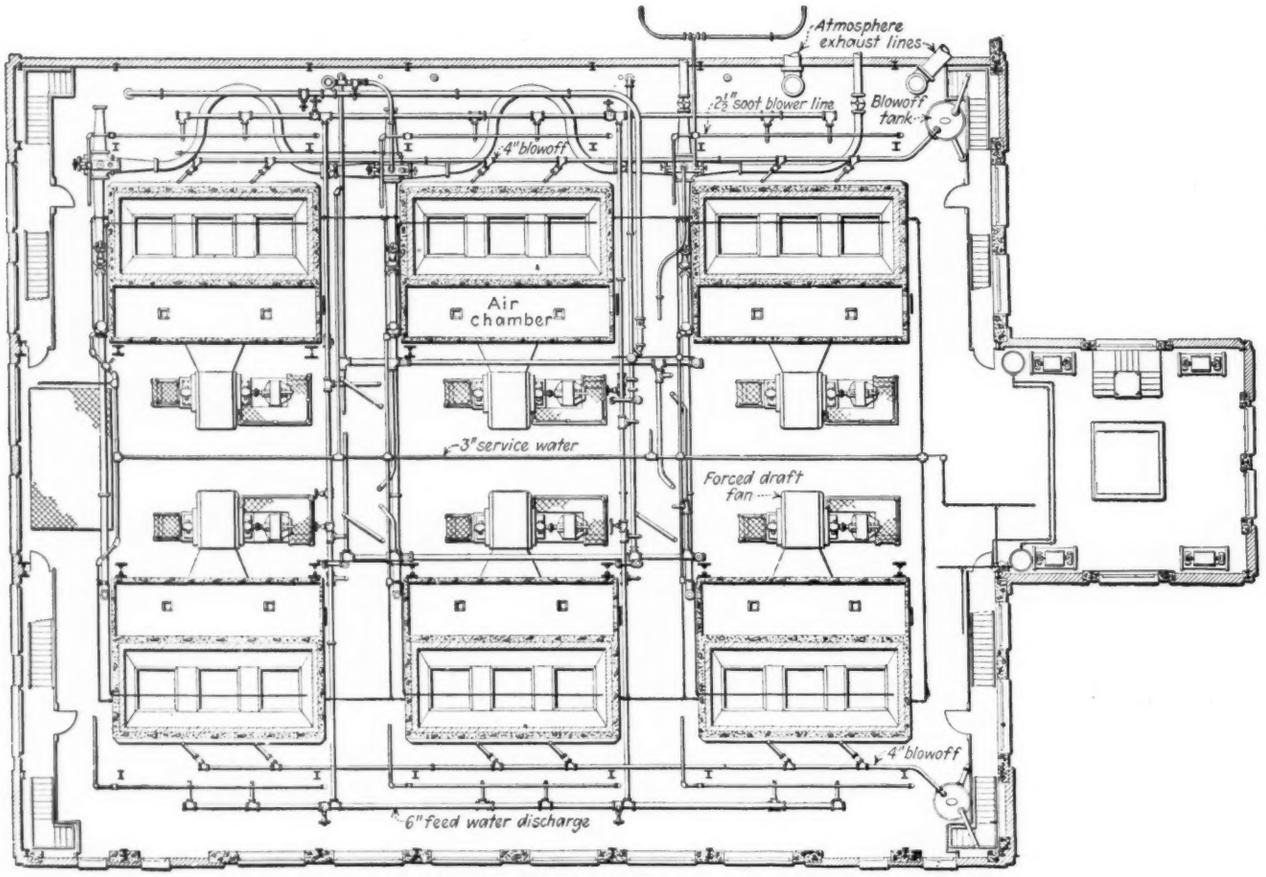


FIG. 13. PLAN OF BOILER-HOUSE AND FANROOM FLOOR LEVEL

20 to 12 in., although this does not apply to the first unit, which, to meet temporary needs, was divided into two machines. Here a 10-in. line from the side of the cross leads to one turbine, and a 10-in. load from the end of the cross serves the other machine. Double offset 12-in. U-bends, through 12 x 20-in. reducers, connect these various cross-fittings, so that the pressure between units may be equalized and any turbine may draw upon any boiler unit in the plant. All the steam piping is covered with 85 per cent magnesia. On the high-pressure line double 1½-in. covering is employed and on the low-pressure lines, standard thicknesses.

Duplicate coal-handling equipment has been provided. Coal comes in on two tracks, each having an unloading hopper 80 ft. long, so that four cars may be dumped at the same time. From the track hoppers, apron feeders transfer the coal to four-roll crushers, delivering to

have not been installed, but provision has been made for them and a platform built at the same level.

Unusual precautions have been taken in the layout of the feed-water system, shown diagrammatically in Fig. 12. In the hot-well piping six headers have been provided and their uses will become apparent. These headers are cross-connected to give the utmost flexibility and to provide more than one passage to the hotwell tank. Likewise, there are two paths from the hotwell tank to the feed-water heater, and around the latter there is a bypass to the suction of the boiler-feed pumps. Between the pumps and the boilers duplicate lines and headers have been provided, and between these two supply lines at the boiler there are two cross-connections, one containing a feed-water regulator and the other open, so that the feed may have either automatic or hand control.

From each main condenser the condensed steam is taken by a motor-driven condensate pump and forced through the after-condenser for the evactor steam-jet type of air pump to a 6-in. condensate header running the entire length of the turbine room to serve all the condensers installed. The condensate from the after-coolers is also collected in this line. From this header there is connection to each of the three hotwell tanks serving the three boiler units. These tanks, located at grade level on the floor below the fanroom, are 96 in. in diameter and 26 ft. long. When evaporators are installed as planned, make-up water will be admitted from the 6-in. evaporator water header through gate and float valves. Temporarily, this header gets its supply from the general water header, to which it is cross-connected. Should the pressure of the water supply be too low, one of the hotwell pumps may draw on the general supply header and deliver to the emergency header, from which it reaches the evaporator water header through check and gate valves and thence to the tanks as before.

There is a motor-driven hotwell pump for each tank, and in addition, a turbine-driven emergency pump which may take the place of any one of the three pumps normally used. From the hotwell tanks feed water flows to an 8-in. hotwell-pump suction header and thence to the pumps by gravity. The suction is double, the other source being the general water-supply header previously mentioned. These pumps also have double discharge connections, one leading to the hotwell-pump discharge header and the other to the emergency water-supply header. Between the two headers there is a cross-connection with a check valve opening toward the discharge header. From the latter 5-in. risers with gate and float valves lead to the two feed-water heaters serving the three boiler units, while 6-in. lines bypassing the feed-water heaters, lead directly to the feed-pump suction header. Each of the two heaters has a capacity of 300,000 lb. of water per hour. The heaters are located on a balcony above the boiler-room floor. The outlet from each heater divides into two 8-in. lines which drop into 8-in. headers beneath the boiler-room floor, one on either side and running the entire length of the boiler house. Each boiler-feed pump has a suction connection of either header. There are four pumps; three of them are electrically driven by 175-hp. direct-current motors with field control. The pump consists of two four-stage compartments connected in series, giving eight stages in all, as the unit is intended to operate against heads up to 720 ft. at a speed not exceeding 1,200 r.p.m. Special excess-pressure regulators are to be provided to keep a constant differential between the discharge pressure of the pump and the boiler pressure. A four-stage turbine-driven pump serves as a reserve for emergency use.

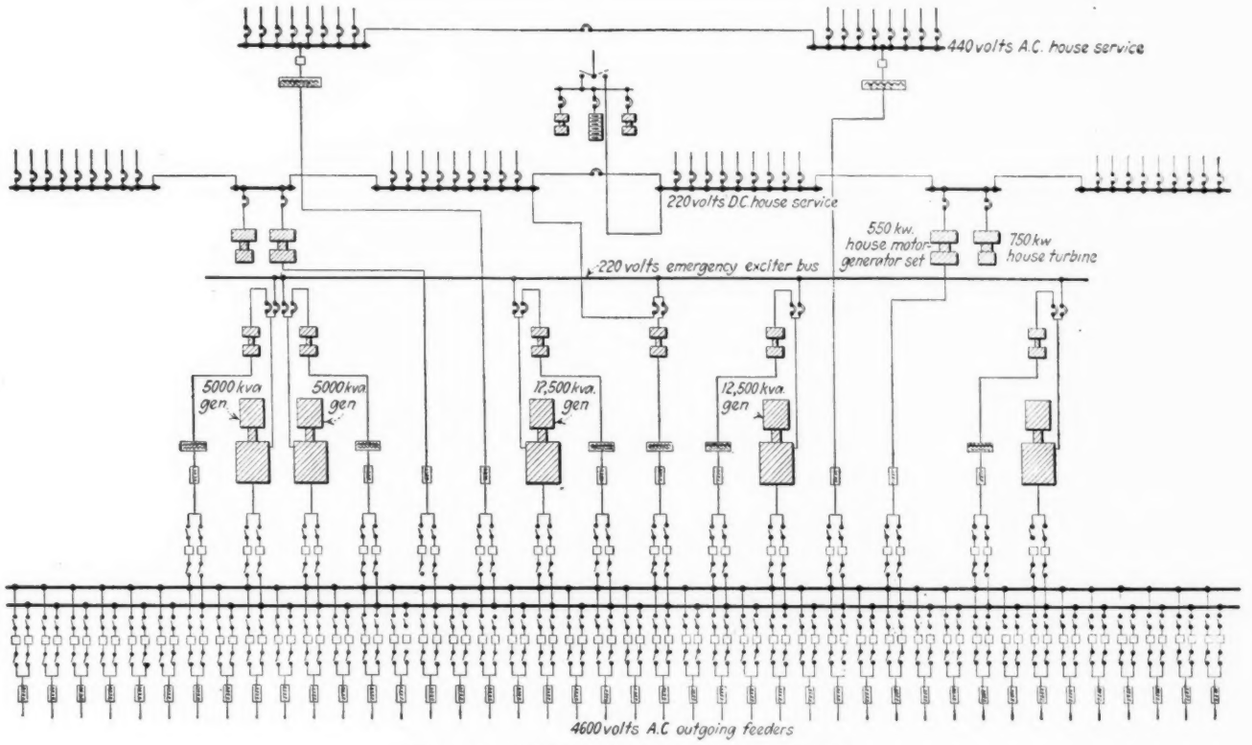

440 volts A.C. house service
220 volts D.C. house service
550 kw. house motor-generator set
750 kw. house turbine
220 volts emergency exciter bus
5000 kva. gen.
5000 kva. gen.
12,500 kva. gen.
12,500 kva. gen.
4600 volts A.C. outgoing feeders

FIG. 14. SINGLE-LINE WIRING DIAGRAM

To correspond with the balance of the system, the discharge from each pump branches out into two 6-in. lines which cross the boiler room and tie into two headers on either side, thus furnishing a duplicate system of headers for either row of boilers. From either header there is a connection to each boiler and in each of these lines is a venturi meter. Between the two lines there are two cross-connections, one containing a feed-water regulator and the other an open line, so that the water may be fed automatically or by hand.

In the turbine room the first unit has been split up into two machines for the reasons previously given. These turbo-generators are intended for condensing operation, but may be operated non-condensing when it is desired to supply the exhaust to the heating system serving the eastern half of the works. This heating had been done previously with the exhaust steam from the forge shop. When the latter is moved, it is proposed to install a non-condensing turbine in the

western half of the premises, the exhaust from which would be utilized for heating that section. The high-pressure steam connection now running to the forge shop will be extended to this turbine.

When operating condensing, each of the two turbo-generator units has a rated capacity of 5,000 kva., which is reduced to 3,000 kva. for non-condensing operation. Under the former operating condition each machine will deliver 4,000-kw. at 80 per cent power factor. Three-phase 60-cycle current is generated at 4,600 volts and the speed is 3,600 r.p.m. The units are designed for a normal steam pressure of 200 lb. gage at the throttle, 100 deg. superheat and 28 in. vacuum, referred to a 30-in. barometer at the exhaust nozzle. The turbines are of the straight reaction type.

The heavy structural-steel turbine foundation, at a level 35 ft. below the turbine-room floor, or practically at grade, rests on a heavy concrete mat anchored with numerous bolts and channels and wing plates at the sides of the vertical columns. Each turbine is served by a surface condenser supported by lugs from the steel foundation. The condenser has 9,500 sq.ft. of active surface which reduces to 2.4 sq.ft. per kilowatt of generator rating. The condenser auxiliaries, which are driven by direct-current motors with variable-speed regulation, consist of an 18-in. circulating pump, 4-in. condensate pump and an air pump of the evactor type with a two-stage steam jet, intercooler and surface-type aftercooler. Connection to the turbine is through a 48-in. cast-iron make-up piece and a back-outlet gate valve through which the steam may pass to the condenser or through the back outlet to a tee from which a 24-in. line will discharge it to atmosphere or through the other outlet of the tee to the heating system.

FIG. 15. CHARLES H. WHITE

With city water to be used for condenser cooling purposes, a cooling tower was essential, and it was necessary to locate it over a double-deck loading platform, the base resting 33 ft. above grade on a heavy steel and concrete framework. The design of the foundation was complicated, as it was necessary to place beneath the tower a storage basin 3 ft. deep. The vertical columns of the framework are joined by heavy concrete beams with structural-steel angle frames. To withstand severe wind stresses, exceptionally heavy anchorage into large concrete bases was provided for the vertical columns.

A combined natural- and induced-draft type of tower was selected on account of its adaptability and high over-all efficiency. At the present time the tower consists of a battery of nine standard cooling units, each designed to handle a normal capacity of 2,000 gal. per min., but in case of emergency the total capacity may be raised up to 25,000 gal. per min. The tower is the largest of its kind in the world. The loading platform is nearly a half mile long, and there is space for indefinite extension of the tower as the capacity of the plant is increased.

Each cooling unit is equipped with two fans 120 in. in diameter, which operate at 200 r.p.m., when the tower is handling the normal quantity of water. By placing the fans above the filling and operating by induced draft, the head against which the water is pumped is reduced by the vertical space required by the fans, so that the power for pumping is correspondingly reduced. A further advantage of the above arrangement is that in winter weather ice cannot form on the fan blades, as the latter are being brushed continually by warm air while the tower is in operation. The structure has been built considerably higher than required by the location of the fans to provide a chimney for natural-draft operation. At times of light load or during the cooler months of the year, the fans may be shut down and the tower operated under straight natural draft. The unit arrangement gives a high degree of flexibility, as any number of units may be operated either on natural draft or on mechanical draft. In this way the plant may be run continually at its maximum point of efficiency. Draft and capacity regulation is made possible by an ingenious damper arrangement located inside of the tower and controlled from the switchboard at the power house. This damper control shunts the air through the fans when it is desired to run the tower under mechanical draft, or it allows the air to pass directly through the filling and into the chimney when operating under natural draft.

From the circulating-water diagram, Fig. 12, it will be seen that the condenser cooling water is forced through the condensers by the circulating pumps into 24-in. steel lines which deliver to a 36-in. circulating-water discharge header. This header runs underground to the cooling tower, and there is a 12-in. connection to each of the nine sections of the tower. From the collecting basin or reservoir underneath the tower, six 18-in. lines tie into a 36-in. circulating-water suction header, from which the pumps at the condenser get their supply.

Two buses are provided and the electrical system as a whole is in duplicate. The generator switches are on the same level as the machines, the connecting leads between passing under the turbine-room floor. A switching compartment is shown in Fig. 6: Protection for each phase from the Y of the generator to

the switch connection is afforded by balanced relays. Thus these relays protect the generator windings and the bus run. Following in order, connections from the oil switches drop vertically to the main bus, then to the feeder switches, reactors and into the cable vault, from which the leads pass underground into the system. All step-down transformers are located at the point of service. At present the reactors are not required, but will be installed with the next 10,000-kw. unit.

With the double bus system, it is quite convenient for the present to carry outside purchased service on one and plant service of the other. The control boards are located on a gallery opening off the turbine room. Here the unit system has been followed and each unit comprises four independent boards arranged in pairs back to back, one for wattmeters, one for generator and auxiliary control, one for feeder control and the fourth for relays. This makes possible the addition of unit board systems as the plant is enlarged, without interfering with the equipment installed. An entire board for wattmeters was essential, as every feeder is metered. The records from these meters are used by the factory management as a guide to regulate the load in each department, the idea being to carry as uniform a load as possible, starting quickly to maximum and ending sharply. On the floor below the turbine room a control board for auxiliary motors has been provided. Here every motor feeder has individual protection, consisting of a circuit breaker and oil switch. Except when a breaker goes out, the operator has no occasion to use this board, as the motors are controlled at the point of service.

Feeder and generator switches and reactors are mounted in cells of reinforced concrete with transite doors. On feeders going to the oven transformers, which are located on the roofs of assembly buildings, lightning arresters are provided. These are the only feeders which terminate overhead and need this protection. To important points of service duct lines are installed for double feeders, but as yet the duplicate lines are not in place.

All control circuits, such as current and potential transformer circuits and solenoid control, are spliceless. The connections are taken out individually to switch-boxes on the wall, where it is an easy matter to test out any circuit in case of trouble.

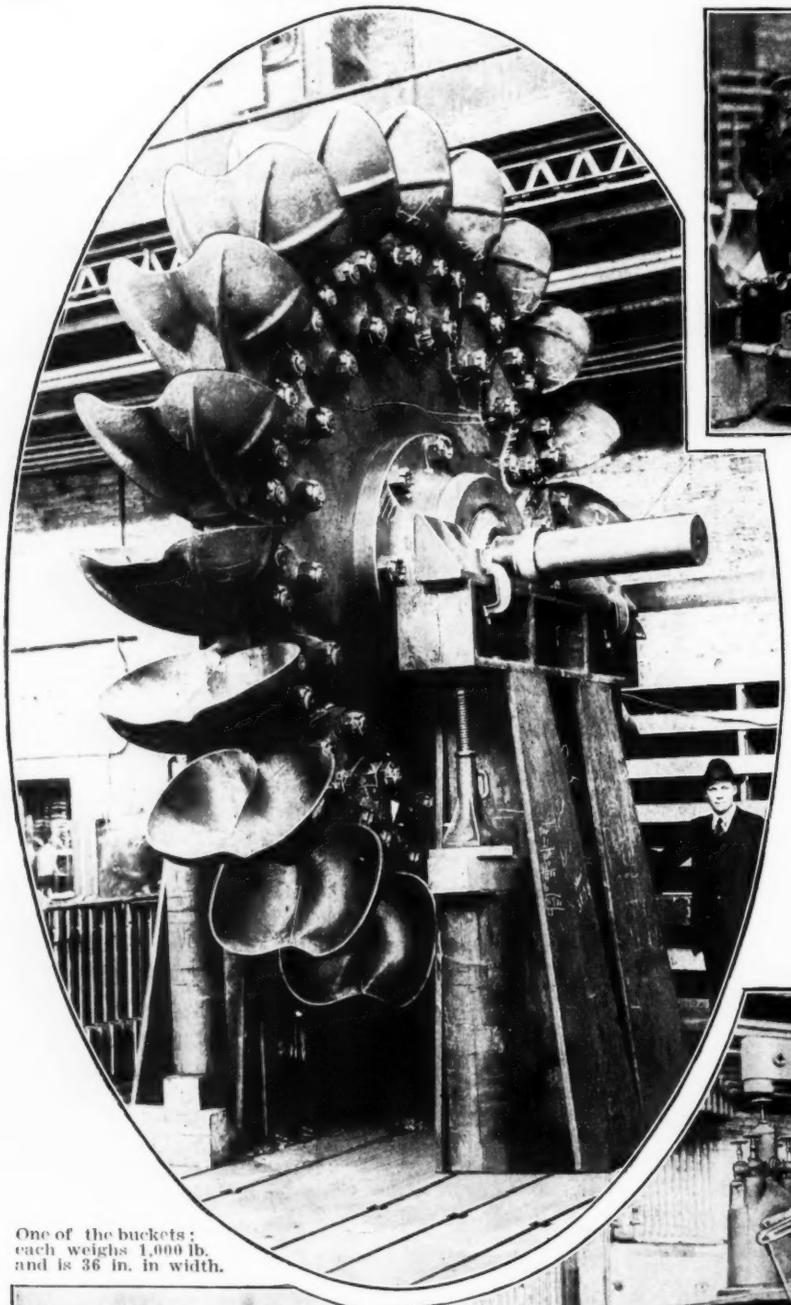
The ultimate plans for the station include the installation of two 750-kw. non-condensing turbines gear-connected to direct-current generators which will supply the power for the operation of station auxiliary motors. There will also be two 500-kw. synchronous-motor-generator sets for the same purpose. These motor-generators will float on the line between the 4,600-volt buses and the 220-volt direct-current auxiliary buses. It is the intention that the steam-turbine unit will supply sufficient exhaust steam to maintain the heat balance of the station, the back pressure on the exhaust steam system acting upon the turbine governor determining the load to be carried by the steam unit. Any excess current over that required for the auxiliaries will feed back into the high-tension buses through the synchronous-motor-generator set, the synchronous motor in this case acting as a generator. If too little direct current is generated with the steam necessary to maintain the heat balance, the additional energy required will be supplied from either of the main buses through the motor-generator set.

The power plant was designed by Smith, Hinchman & Grylls, architects and engineers, in collaboration with Dodge Brothers' engineers, and the erection of the plant was carried out by the construction department under the personal direction of Charles H. White, superintendent of power and construction for Dodge Brothers. Ground was broken for the plant on May 18, 1920; the first steel columns were set Aug. 5, 1920; the drying out fire under the boilers was lighted Feb. 1, 1921, and the power plant made ready for operation on May 1, 1921.

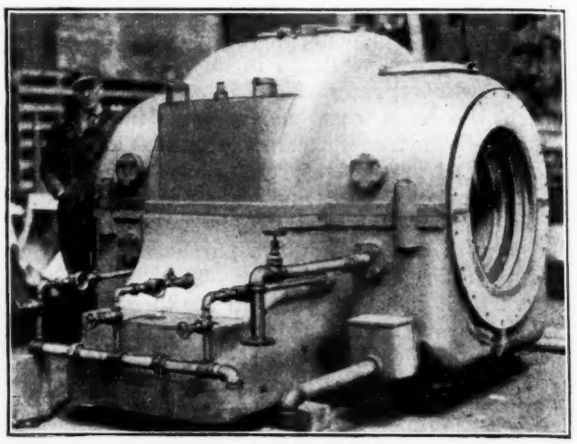
PRESENT EQUIPMENT OF DODGE BROTHERS POWER PLANT

No.	Equipment	Kind	Size	Use	Operating Conditions	Maker
6	Boilers	Water-tube	12,870 sq.ft	Generate steam	225 lb., 100 deg., superheat, forced draft	D. Connelly Boiler Co.
6	Stokers	Underfeed	12-retort, extra long	Serve boilers	Driven by 20-hp. G.E. motor, d.c., 200-1,200 r.p.m.	Sanford Riley Stoker Co.
6	Fans	Turbo-vane	54,200 c.f.m.	Forced draft	Driven by 100-hp., d.c., G.E. motor, 325-950 r.p.m.	B. F. Sturtevant Co.
6	Superheaters	Foster		Superheat steam	100 deg. F. superheat	Power Specialty Co.
3	Pumps	8-stage centrifugal	5-in., 450 g.p.m.	Boiler feed	Driven by 175-hp., d.c., G.E. motor, 1,100 r.p.m.	De Laval Steam Turbine Co.
1	Pump	4-stage centrifugal	600 g.p.m.	Boiler feed	Driven by De Laval 200 hp. turbine, 2,400 r.p.m.	De Laval Steam Turbine Co.
2	Heaters	Open	360,000 lb. per hr., 100-220 deg. F.	Feed water	Exhaust steam	Harrison Safety Boiler Co.
2	Conveyors	Apron feeders	30 in. wide; 97 and 104 ft. long	Coal from track hoppers to crushers	Driven by 10-hp. G.E. ind. motor, 1,200 r.p.m.	Link Belt Co.
2	Crushers	Four-roll	24x36 in., 75 tons per hr.	Crush coal	Driven by 40-hp. G.E. ind. motor, 1,200 r.p.m.	Link Belt Co.
2	Conveyors	Belt	30-in. wide, 63 and 78 ft. long	Coal from crushers to bucket conv	Driven by 5-hp. G.E. ind. motor, 1,200 r.p.m.	Link Belt Co.
2	Conveyors	Peck carriers	24x30 in., 105 ft. centers	Elevate coal to bunker level	Driven by 15-hp. G.E. ind. motor, 1,200 r.p.m.	Link Belt Co.
2	Conveyors	Belt	24-in. wide, 175 ft. long	Distribute coal to bunkers	Driven by 10-hp. G.E. ind. motor, 1,200 r.p.m.	Link Belt Co.
3	Pumps	Centrifugal	4-in	Hotwell	Driven by 40-hp. G.E. ind. motor, 1,200 r.p.m.	Allis-Chalmers Co.
2	Pumps	Centrifugal	2-in	House service	Driven by 7½-hp. G.E. ind. motor, 1,750 r.p.m.	Allis-Chalmers Co.
2	Turbines	Cond. non-cond	5,000 kva	Generating units	200 lb. press., 100 deg. superheat, 3,600 r.p.m.	Allis-Chalmers Co.
2	Generators	A.C.	5,000 kva	Generating units	3-phase, 60-cycle 4,600-V., 3,600 r.p.m.	Allis-Chalmers Co.
2	Condensers	Surface	9,500 sq.ft.	Serve turbines	28-in. vacuum	Allis-Chalmers Co.
2	Pumps	Centrifugal	18-in	Condenser circulating	Driven by 200-hp. G.E., d.c. motor, 600 r.p.m.	Allis-Chalmers Co.
2	Pumps	Centrifugal	4-in	Condenser condensate	Driven by 10-hp. G.E., d.c. motor, 1,150 r.p.m.	Allis-Chalmers Co.
2	Evactors	Two-stage with after-cooler		Condenser air pump		Allis-Chalmers Co.
1	Pump	Centrifugal	4-in	Emergency	Driven by Moore 40-hp. turbine, 1,750 r.p.m.	Allis-Chalmers Co.
1	Crane	Electric bridge	50-ton, 4-motor	Turbine room	58-ft. span	Northern Engin'g Co.
1	Cooling tower	Natural and induced draft	9 element, 18,000 g.p.m.	Condenser circ. water	105 to 85 deg., temp. 72 deg., humidity 69 per cent	Wheeler Cond. & Eng. Co.
18	Fans	Disk	120 in	Serve cooling tower	Driven by 25-hp. G.E. ind. motor, 900 r.p.m.	Wheeler Cond. & Eng. Co.

Vulcan soot blowers, 14 element; Copes feed-water regulators; Schutte & Koerting stop check valves; Yarway blow-off valves; Cranetilt traps; Allis-Chalmers 100-kw. exciters; 4,600 volt, switches and control, Westinghouse; Insulators and fittings, Gen'l Device and Fitting Co.; 440-volt control, Industrial Controller Co.; 220-volt d.c. control, General Electric



One of the buckets; each weighs 1,000 lb. and is 36 in. in width.

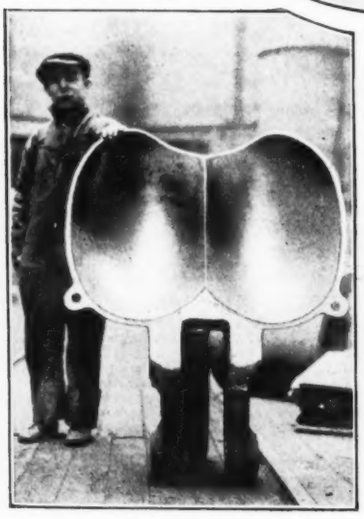


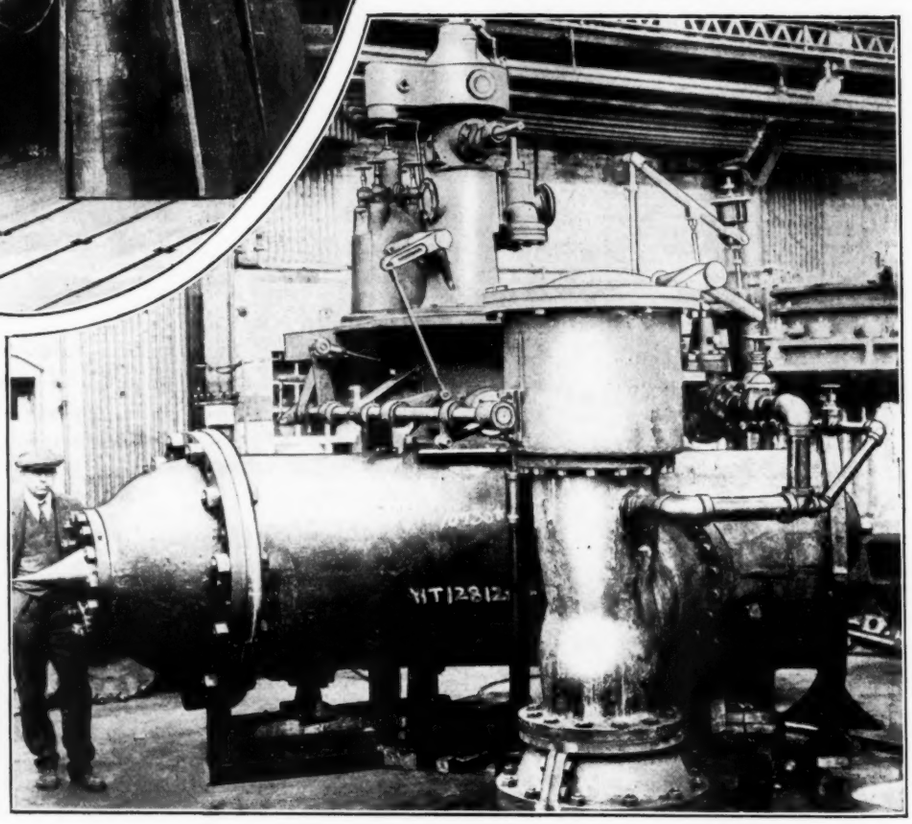
One of the bearings. The shells are 72 in. long by 24¾ in. bore.

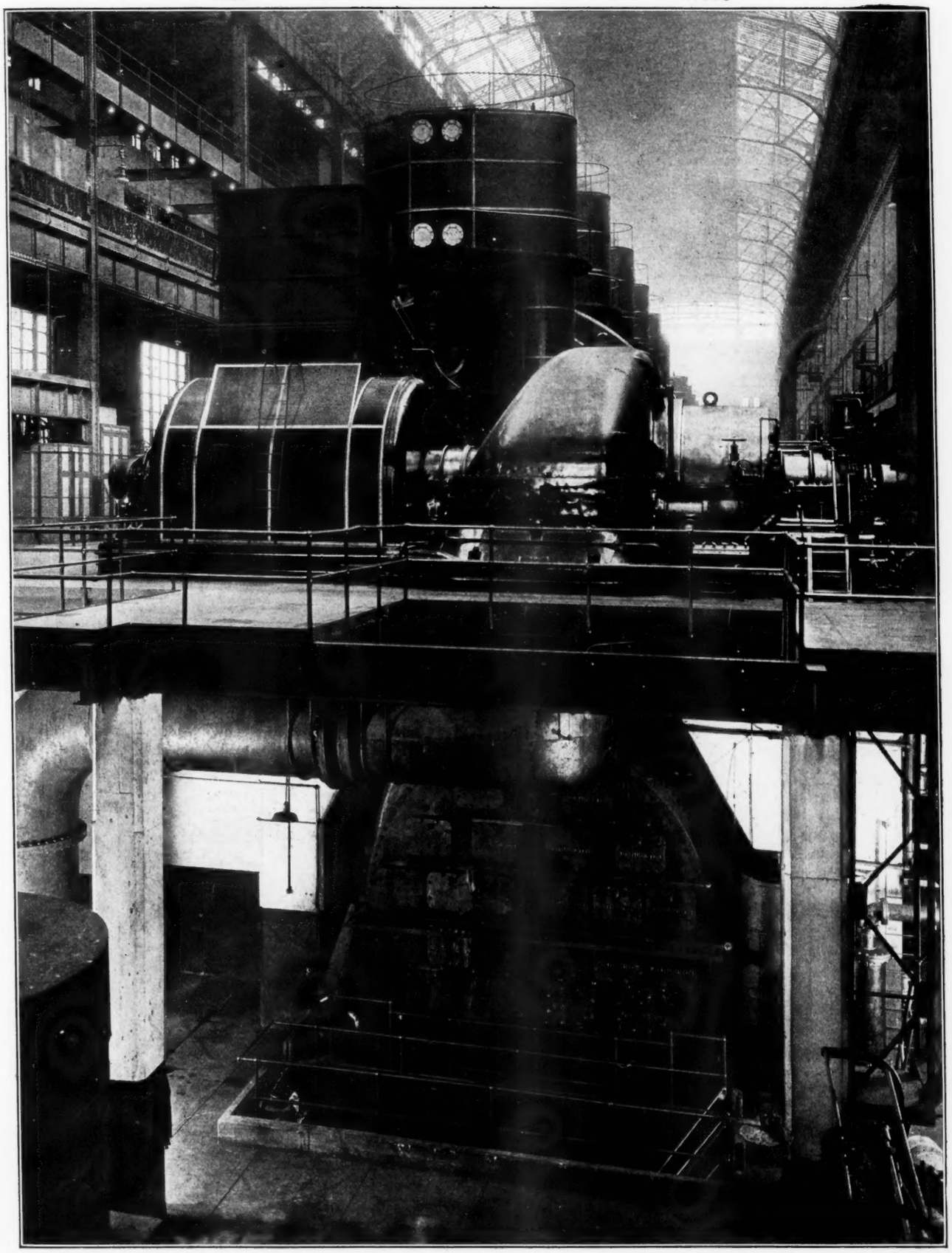
A 30,000 Horsepower Impulse Water Turbine

These views give a good idea of the unusual size of the hydro-electric equipment of the new Caribou Plant of the Great Western Power Co., in California. The available head is 1,008 ft., the speed of the wheel is 171 r.p.m. and the power to be developed by each of the two units is 30,000 hp. The equipment was built by Allis-Chalmers Co. The assembled wheel, which weighs 25 tons, is shown in the oval.

Assembly of needle regulating nozzle, pressure regulator and governor.







The Old and the New—A Comparison

The total maximum capacity of the whole row of double reciprocating units in the background of this picture is 37,500 kw., and yet the turbo-generator in the foreground can produce 35,000 kw. A better illustration could scarcely be obtained of the economy of space of the modern steam turbine over the old-style reciprocating engine. The picture was taken in the 59th street powerhouse of the Interborough Rapid Transit Co., New York City. Results of a test on the turbine and condenser were incorporated in a paper for the A. S. M. E. spring meeting, an abstract of which appears in this issue of *Power*.

Diesel Engines for Small Central Stations

Cost of Operation in the Power Plant of Hiawatha Light, Power and Ice Co.—Installation of Oil Engines Effected Large Economies

IN PRACTICALLY all industries the cost of power plays a minor part in the determination of the cost of production. The central station is essentially a manufacturing plant, its product being the electrical energy delivered to the transmission lines. Unlike other industries, in the central station the cost of power is the total production cost. For this reason a greater necessity exists in the latter industry to secure the lowest possible power costs.

The large plants, ranging from 5,000 kw. upwards, are able to use steam-turbine units and other steam equipment possessing high economy. As a result due to the advance in steam engineering, the largest steam central stations have been able to deliver a kilowatt-hour at the switchboard at an expense of approximately 18,500 B.t.u. in the coal. The number of central stations below 1,000 kw. capacity vastly exceeds the number of plants having a capacity above this. These small stations cannot secure the high efficiency obtainable in the large power stations for steam equipment of small capacities do not possess a high efficiency.

With the high coal and labor costs that are likely to prevail in the future, the burden carried by the executives of the small stations will become even harder than at present. It is imperative that a more economical process of electric generation be adopted if the smaller stations continue to exist. More improved steam apparatus must be provided, or the plants will be compelled to turn to other forms of power machinery.

This tendency toward the use of more economical prime movers, such as Diesel oil engines, is very apparent, especially in the Middle Western States, where a large number of electrical generating plants have installed oil engines in recent years.

The central station of the Hiawatha Light, Power and Ice Co., of Hiawatha, Kan., is a striking example of this drift of the small plants toward the oil engine. This concern for a number of years operated a steam-driven plant. The equipment consisted of horizontal-tubular boilers, a Corliss, a high-speed steam engine and an ammonia compressor along with the usual accessories of a non-condensing plant where both electrical energy and distilled-water ice are manufactured.

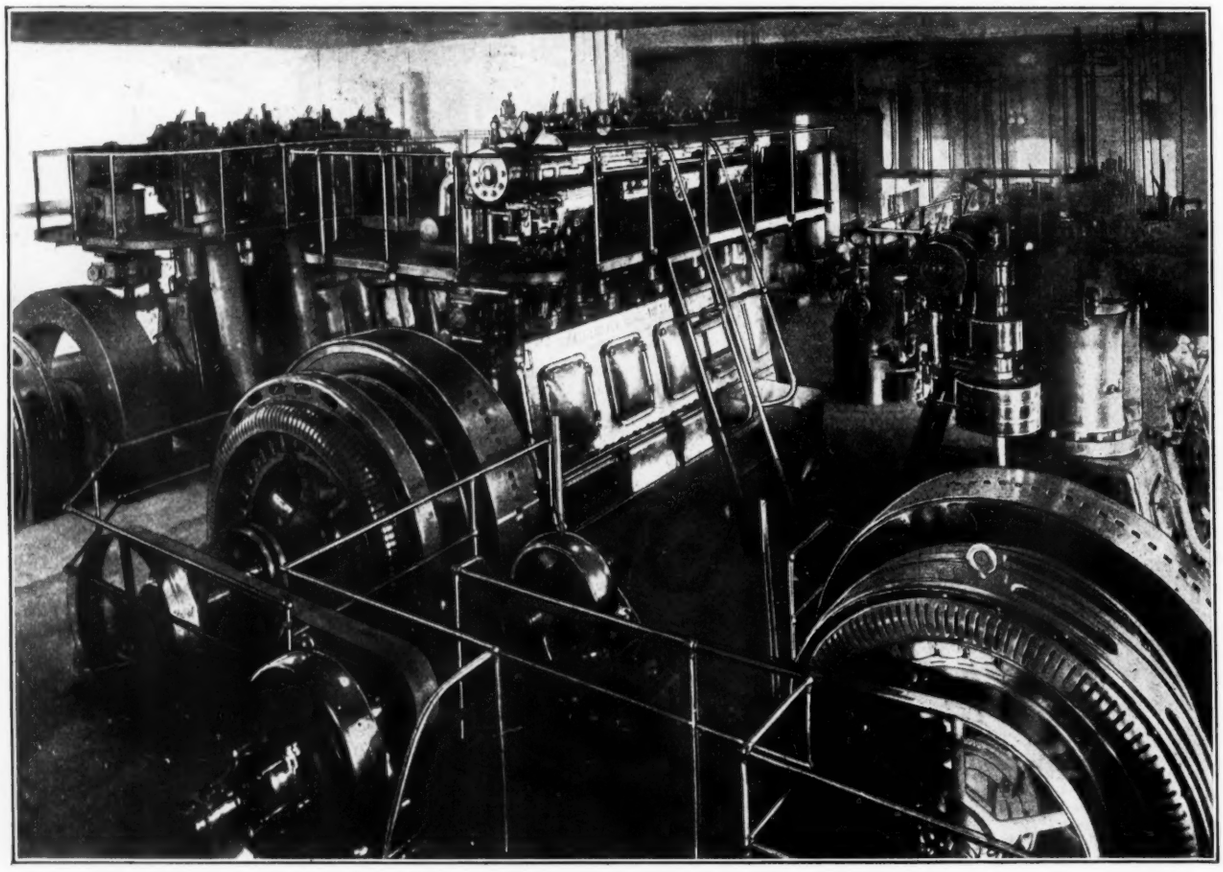


FIG. 1. ENGINE ROOM OF THE HIAWATHA PLANT, SHOWING THREE DIESEL ENGINES

Even as early as 1914 the increasing cost of fuel, labor, etc., had made the situation of this station, as of many others, an extremely serious one. It was practically impossible for any central station to increase the rate to conform to the increased costs without arousing

public protest. With the Hiawatha company the raising of rates was made impossible by the presence of a municipal light plant in the city. The necessity of more economical production methods was made imperative by the increasing power demands of several neighboring towns that had contracted with the company for electric current.

In arriving at a choice of new prime movers, the main thought was that of economical reliable operation. The final decision was to purchase a Diesel oil engine, a 250-hp. Busch-Sulzer being purchased and installed in 1915 alongside the old steam equipment. The question of reliability of the Diesel, which for some reason is still uppermost in the minds of many engineers, caused the management to keep the boilers under steam. It was soon found that the oil-engine unit was fully as reliable as were the steam units; in fact, the factor of reliability favored the Diesel. The operation of the Diesel was extremely satisfactory, and the economy was so marked that lower electrical rates were put into effect. The decrease in rates naturally increased the load demand, which in turn necessitated the addition of more horsepower capacity. As a consequence, in 1917 a second Busch-Sulzer engine was installed, this one being rated at 365 horsepower.

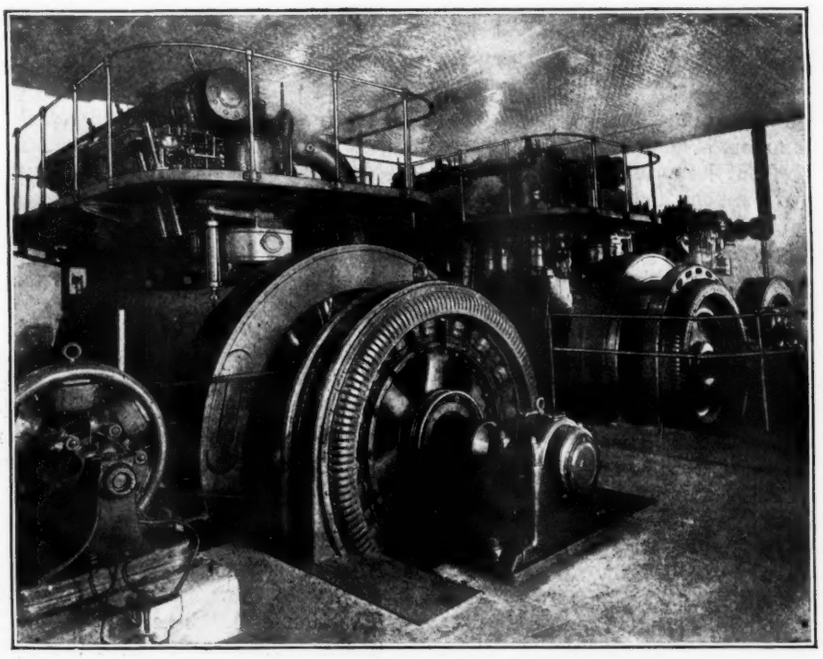


FIG. 2. FIRST DIESEL INSTALLED IN HIAWATHA PLANT

As all who are familiar with the central-station situation are aware, the rising cost of labor, fuel and supplies from 1917 onward was extremely distressing to all central stations and increased rates were advocated and put into effect. Nevertheless, the marked economy of the Diesels in the Hiawatha plant enabled the management to operate under the old schedule of rates. In 1919 a third unit, a 365-hp. Busch-Sulzer Diesel, was installed.

Prior to the purchase of the third engine the steam equipment had been used to operate the distilled-water ice plant. This steam plant was now abandoned and a raw-water ice system substituted. The compressor was motor-driven as was also the other ice machinery.

The engineers who operated the steam plant were retained and learned to handle the oil engines under the guidance of the erecting engineer. The engine-room force make all necessary repairs and running adjustments. A plan of giving each engine a general overhauling at the end of three years' operation has been adopted. At these overhauling periods a shop engineer is secured, who does the heavy repairs. So far the engines have required no large or expensive part replacement, the wear being confined in the main to the fuel pump parts, needle valves and governor rollers. Although one unit has been in service for four and one-half years, the cylinder clearance is still small, no new liners so far being required. Much of the success of this Diesel central station is attributed to the adoption of a regular schedule of inspection. In this way the engine valves are reground every three months, the other vital parts being inspected at stated intervals; the work is so arranged that each day one definite part is looked into and adjustment made.

In Table I appears the yearly cost of power with the Diesel plant. The average production cost, eliminating all overhead charges, amounts to $0.0137 per kw.-hr.; including the fixed charges the cost per kilowatt-hour amounts to $0.0231. This, although the load factor is low, is considerably below present costs in steam plants of like capacities.

In arriving at the costs as outlined in Tables I and II, the fuel charge represents the actual cost of fuel oil

TABLE I. COST OF PRODUCING CURRENT WITH DIESEL ENGINES IN 1920

Month 1920	Fuel — Fuel	Fuel — Lubricants — Lubrication	Labor — Station Operation	Labor — Manager	Maintenance and Supplies — Extra Labor	Maintenance and Supplies — Supplies Repairs	Maintenance and Supplies — Over-Hauling	Auxiliaries — Current for Sta. Lights	Auxiliaries — Current for Pumps	Fixed Charges	Total Cost	Kw.-Hr. Generated	Total Cost per Kw.-Hr.
Jan.	$373.24	$128.19	$258.75	$60.00	$80.00	$141.19	.....	$20.26	$60.00	$673.61	$1,802.24	90,906	$0.0198
Feb.	327.62	128.19	258.75	60.00	90.00	264.32	.....	23.78	60.00	673.61	1,893.27	86,222	.0214
March	311.16	128.19	345.00	60.00	51.75	324.66	.....	25.06	60.00	673.61	1,986.43	90,711	.0219
April	327.31	128.19	345.00	60.00	.....	211.42	.....	16.00	60.00	675.52	1,830.44	102,797	.0178
May	382.00	128.19	285.00	60.00	.....	9.00	.....	58.41	60.00	675.52	1,665.12	116,731	.0140
June	350.26	128.19	265.00	60.00	.....	1,043.25	.....	60.00	60.00	675.52	2,649.22	105,984	.0250
July	716.86	140.00	260.00	60.00	.....	258.29	.....	25.00	90.00	1,255.00	2,812.15	127,235	.0221
Aug.	1,067.73	140.00	260.00	60.00	45.00	10.65	.....	14.00	75.00	1,255.00	2,934.38	90,841	.0323
Sept.	1,054.80	140.00	260.00	60.00	.....	178.30	.....	14.00	75.00	1,255.00	3,044.10	111,066	.0274
Oct.	865.55	140.00	260.00	60.00	.....	26.00	.....	14.00	75.00	1,255.00	2,702.55	109,555	.0246
Nov.	747.00	140.00	260.00	60.00	.....	276.34	$140.85	14.00	75.00	1,255.00	2,975.19	106,072	.0280
Dec.	715.35	140.00	260.00	60.00	.....	203.20	140.85	14.00	90.00	1,255.00	2,885.40	112,644	.0256
Totals.	$7,238.88	$1,609.14	$3,317.50	$720.00	$256.75	$2,946.62	$281.70	$298.51	$840.00	$11,577.39	$29,190.49	1,250,764	$0.023

used each month. The increase after July 1 is due to the purchase of oil in the open market at a price in advance of the contract in force prior to July. The supply and repair items cover the cost of all supplies and repairs for the engine room. The lubrication charge represents the cost of the oil used each day, together with that used to replenish the crankcase oil. It is somewhat higher than is usual since the filtering equipment fails to recover the oil completely. Overhauling is the cost of the general overhaul given the engines every three years, being divided into 36 equal monthly charges. The manager charge is that portion of the manager's time that is devoted to the power plant. Interest is figured at 6 per cent, depreciation is placed at 7½ per cent for the engines, 4 per cent for the buildings and 4 per cent for the electrical equipment. The overhead also includes all taxes on the station.

TABLE II. RESUME OF COSTS FOR THE YEAR 1920

		Cost per 1 Kw.-Hr.
Fuel	$7,238.88	$0.0058
Lubrication	1,609.14	0.0013
Labor	4,037.50	0.0029
Maintenance and supplies	3,495.07	0.0028
Auxiliaries	1,222.51	0.0009
Fixed charges	11,587.39	0.0094
Total	$29,190.49	$0.0231
Output	1,250,764 Kw.-hr	
Over-all cost per kw.-hr		$0.0231

Specifications for Refrigerating Apparatus

By G. H. CRAWFORD

THE writing of good specifications by engineers is by no means common. This is not because of lack of knowledge, but because the average engineer is too busy to devote much thought to the subject. Yet the results of a poorly written specification often lead to most unpleasant situations. It is only necessary for one to recall some unhappy purchase due to a faulty specification, to realize this point.

The object of a specification is to set down concisely yet clearly and completely, the requirements of a purchase. For large purchases the specification is usually written separately from the contract; for small purchases the two are usually merged in one.

It is not difficult to get up a specification, and it requires no particular knack of writing. It does, however, require that the engineer know what he himself wishes to obtain. The most important part lies in the study of the article or apparatus to be bought.

In the army written orders are of every-day occurrence. One officer formulated the simple minimum requirement for any good order. It must contain information as to "what, when, where and who." He called these the four w's of an order. Similarly, a good specification has certain minimum requirements which can be formulated. A sample of such a form used for a number of years by the writer is shown herewith. The use of a form prevents omission of necessary information and allows the engineer's energy to be devoted to a description of the apparatus wanted, without an unconcious dread that he has forgotten something important.

General Principles

There are a few general principles in writing the engineering part of specifications which should be understood. One of the most important of these is fair play with the manufacturer. The specification should be written with the idea that it will form the basis of a contract with some other party. As such it should be borne in mind that a good contract is one that is to the advantage of both parties—buyer and seller.

Some refrigerating engineers who thoroughly know what they want, specify in detail just the machinery or apparatus, special or otherwise, but ask for no guarantees aside from those covering material and workmanship. Others specify in general what is desired, state the results required and call for guarantees as to performance. They leave to the manufacturer the details of how such results are to be obtained. Either of these methods is good and will lead to satisfactory relations between the buyer and seller. Some engineers, however, try to specify details, call for special apparatus and then require performance guarantees. Trouble is the usual result.

Special apparatus has a higher price than standard and usually takes longer to deliver. The wise engineer will endeavor to fill his wants by a careful selection of standard apparatus.

Many engineers claim it is advantageous to purchase all the equipment of a given installation from a single manufacturer. This centralizes the responsibility and usually makes the work of installation simpler. Others prefer to purchase the different parts of a refrigerating plant separately and to superintend the installation themselves. This makes work for the engineer, but usually there is a financial saving that justifies his action.

Erection of Machinery

Erection of machinery is generally a bugbear. The engineer will often require the apparatus specified to be erected completely by the manufacturer. The latter may not know local conditions and therefore has to make his price high enough to cover all contingencies. He generally either loses a lot of money on the erection or makes a lot. Neither is fair. A reasonable way to overcome this difficulty is for the manufacturer to include in his price the services of an erecting engineer for a definite period of time. The purchaser then assumes all other erection expenses; he pays for them at cost and thus he neither loses nor makes any money on this item.

In referring to the form, it will be seen that a title is called for; for instance, "condenser specification." This is for filing purposes. An extra copy of all specifications should be filed, preferably alphabetically under subjects, as "ammonia," "belts," "condenser," etc. A specification file is invaluable where many specifications are to be written. It is a wonderful time and mental effort saver. It is well also to give the specification some reference or specification number so as to tie it in to some piece of work. This also allows a definite follow-up in case of delays in delivery.

The name and address of the manufacturer should be entered on the form to allow easy reference in the future, and is often required. It shows proper attention to detail and saves time all along the line. The manufacturer's telephone number is not out of place, especially if he and the buyer are in the same city.

The "description of articles or apparatus" is the item that calls for the engineer's technical knowledge. This description should be complete but concise. The manufacturer should be allowed as much leeway in details as possible. The standard article, instead of the made-to-order kind, should be used. There is advantage to the purchaser as well as to the manufacturer in standardization. If a repair part is needed, it can be secured quicker or cheaper by having it standard. Under this head sizes should not be shown. The sizes, surfaces, speeds, etc., should appear in a separate part of the specifications. This allows much easier checking all along the line, and checking is essential to overcome human likelihood to error. It also allows the engineer to use the retained copy for a new specification at a later date, by simply changing the sizes, price, etc. If there is to be any erection by the manufacturer, this item should be clearly and completely covered.

The guarantees should be very carefully worded. If one is not sure of his ground, it is best to go slow. A great many performance guarantees are not worth much because of one or more omissions. Experience and past specifications are the best guides. It goes without saying that the specification should include a clause covering the guarantee of workmanship and material. This is simple and will protect the buyer against defective material.

The price is of interest to the engineer, but he should not be unduly subject to the influence of low price. Careful judgment and the necessary calculations should be used to check prices. The obtaining of the lowest prices and best terms are strictly within the province of the purchasing agent. It is well to let the latter attend to these items. By so doing the engineer is relieved of a lot of detail work, and also is cleared of any suspicion of self-interest. But it should be remembered that unless the specification is perfectly clear and definite, nine purchasing agents out of ten will buy at the lowest price with scant regard to quality.

Too much care cannot be given to the instructions regarding shipment. The specifications should include full details as to where and when the shipments are to be made. It is well to include the desired marking of packages, especially for large jobs, where a great deal of material is to be received. The markings assist in keeping receipts orderly and will prevent a lot of uncertainty.

Machinery Drawings

Quite often drawings will be required. It is well to include in the specifications a mention to whom they are to be sent and a list of those desired. This will prevent argument later in case the manufacturer is shy about supplying the necessary drawings. It is well to remember that it is not considered fair to force a manufacturer to send out working drawings of machinery. Foundation drawing, often special, and all pipe layout drawings are not considered confidential and the specification should call for them when they are needed. Such drawings as are supplied should be carefully preserved by the engineer, as they will surely be useful at some later date when alterations or additions to the ammonia piping are made. It is surprising how many plants are without a proper file of drawings covering the system in use. A French engineer was recently in this country working in some large ice-making and packing plants for experience sake. He told the writer that in none of these plants were there layout drawings or records of just what the installations consisted of. In the packing plant, even the size of the engine and compressor were known only by hearsay. Such a state of affairs exists in many plants.

Points that Should Be Covered in Specifications

It is impossible to outline all the points that should be covered in writing refrigerating specifications. The following hints are the results of experience:

Agitators for brine. Give the electrical characteristics of the motor for direct-connected agitators. Also state the size of the tank and the number of agitators in the tank. This will give the manufacturer the necessary information as to the requirements.

Ammonia (anhydrous) is pure as supplied by all reputable manufacturers. It requires little specification aside from the required weight and size of shipping cylinders. The 100-lb. (net) size is the most convenient for ordinary plants.

Brine coolers should be specified for duty as under "compressors," giving the suction pressure and mean temperature of brine in the cooler. A test clause should be inserted with submission of a test report by manufacturer. A safety valve should also be specified.

Calcium chloride may be specified in a manner similar to salt. Calcium comes either granulated or solid. Always specify which is desired.

Chain-drive specifications should state clearly the two pieces of apparatus to be connected together by the chain with their sizes, speeds and power. The ratio of speed reduction should be as small as possible. For compressor drives a spring sprocket is usually called for.

Compressors should be called for according to the studied preference of the engineer. This is the most important single item of the plant. "Volumetric efficiency" is a little-understood term, hard to prove or disprove, therefore it should be avoided. Specify instead the duty desired in definite terms as "tons of ice per day of 24 hours," cooling — gal. of — specific gravity — brine per min. from — °F. to — °F., etc. The term "tons of refrigeration" is hard to prove. In addition to the duty the conditions under which the duty is to be performed must be given, such as speed, suction pressure, discharge pressure, suction-gas superheat, steam i.hp., etc. Reliability is of far more importance in a compressor than a few points of efficiency.

Condensers should be given careful attention. Being subject to rapid corrosion, the material of the pipe and fittings should command serious study. With some water galvanizing is necessary. The design of condenser is interesting, but should not lead to the purchase of freak apparatus. Condensers should be free from all operation attention except cleaning. If one asks for guarantees, he should limit them to gas tightness and condensing pressure. It is necessary to state the quantity and initial temperature of the cooling water and the duty required. For a description of duty follow hints given as to compressors. Sometimes a specification will call for the outlet ammonia liquid temperature, though this is not very important.

Cranes for freezing tanks. The important items to specify are width of room or span of crane, size of rails, clearances, total net load, size and type of hoist, any electrical wiring desired, crane to be free running and when fully loaded to be handled easily by one man.

Hoists for crane. If of electric type, specify characteristics, also the lift, brakes, limit stop, clearances, hook speed, etc. The motor should have damp-proof

insulation. The controller should be of heavy duty design. Do not use a voltage over 220; 110 if possible.

Insulation is an important item in refrigerating plants. The present tendency is more and more toward corkboard and regranulated cork in spite of the high cost of these materials. Lithboard, which is a mixed mineral and vegetable product, is also used a great deal. The tank or room to be insulated should be described and the type of insulation stated. The thickness will depend on the average seasonal difference in temperature between the surroundings and the interior of the refrigerated space. This is different from the piping in the room. The latter must be calculated on the

FORM TO USE AS GUIDE IN WRITING SPECIFICATIONS

Title	Separator for Oil and air, Specification
Specification No.	P. R. 1320
Make	..... Manufacturing Co.
	..... St., New York City
	Phone .....
No. to be supplied	Two (2)
Description	These separators shall be of the type known as Figure M, page 24 ..... Manufacturing Co.'s 1918 catalog. They are to be complete with— Companion flanges Bolts Gaskets Oil gage
Size	4½ in. pipe size
Dimensions	Face to face of flange 13 in. Wide ..... 21 in. High ..... 25 in. Center of pipe to top ..... 10 in. Drip size ..... 1 in. pipe Weight ..... 290 lb.
Erection	None
Guarantee	The manufacturer shall guarantee the separator as to First, workmanship and material for one year, Second, to separate oil and water from air passing through the separator. Third, to be tight for a working pressure of 50 lb. per square inch gage
Price	$ ..... f.o.b. factory or New York stock
Shipment	Prepare to ship March 1, 1919, to .... Machine Co. .... Cold Storage Co. ..... N. J. But do not ship until final instructions are given.
Mark all packages	"Job 5771"
Drawings	Manufacturer shall send to our Engineering Department triplicate prints showing this separator.

maximum difference in temperature. There is such a thing as too thick insulation where the interest on the cost of installation and depreciation outweigh the savings in refrigeration gained by the added thickness.

Packing for piston rods. The specification should be accompanied by a sketch of the stuffing box, and should include a note as to the gas or liquid being packed against, such as ammonia, steam, carbon dioxide, etc. Also give the pressure, speed of the machine and stroke. This allows the manufacturer to pick out his best type of packing for a given service.

Pipe coil specifications should include a reference to the drawing to be used, the number of pieces to be supplied, the size and kind of pipe to be used; that is, steel or wrought iron, standard-weight or extra-heavy, and the kind of joints. A paragraph should be inserted as to the test. It is well to get a test report from the manufacturer. It should be possible to roll a marble through the finished coils about ¼ in. smaller in diameter than the nominal size of the pipe. Thus for 1¼-in. pipe coils a 1-in. diameter marble should roll through. The painting desired should be specified, also a description of the clamps.

Piping is important both as to the material of the pipe and fittings and as to the joints. The connections should be welded as much as possible to avoid joints, but the pieces should be short enough for handling. The joints should be flanged with tongue and groove. Flanges should be screwed and sweated to the pipe. Avoid the use of litharge and glycerin except for temporary joints and where very high temperatures are encountered. Gaskets should be of lead or asbestos superheat type. Rubber will cause trouble. The best fittings are made of malleable iron for screwed fittings, semi-steel for flanged fittings and malleable iron or drop forgings for flanges.

Pumps for water and brine are of many designs. Give the capacity required and the total net head against which the pump must work. This is especially important for centrifugal pumps, as both power and capacity vary greatly for different heads. Pumps are usually bronze-fitted for brine and water. Keep the speed of reciprocating pumps low.

Receivers for ammonia liquid should be specified as to size. Keep the diameter small as the pressure is high. A test report should be required. The liquid level gage should be carefully protected. A small safety valve should be called for to protect against excessive pressures.

Salt for brine should be specified mainly as to its non-corrosive action, on iron and steel when mixed with neutral water to form a brine of a given density. If you are not sure of the required weight of salt, specify the volume of brine of a given freezing point. A 200-lb. bag of salt is a standard and convenient unit.

Germany's Change of Policy Regarding Her Power Resources

Under the impetus of coal shortage, a great coal-saving movement had been started during the war all over Germany. Lignite and even peat were being used in power plants, in spite of the costly additions of equipment required for the purpose; and a large number of water-power projects, some of which were of almost unheard-of magnitude, were studied.

This policy has lately suffered a severe check and reaction has followed. The reason for this is the latest estimate of the country's power resources, outlined in the following tables, wherein the water power has been estimated by assuming all prospects in view or under exploitation for 1,000 years, corresponding with the estimated life of the coal deposits.

GERMANY'S POWER RESOURCES

Bituminous coal	305,000,000,000 tons
Lignite	13,400,000,000 tons
Peat	850,000,000 tons
Water power	7,600,000,000,000 kw.-hr.

EQUIVALENT VALUE IN BITUMINOUS COAL OF GERMANY'S POWER RESOURCES

Bituminous coal	305,000,000,000 tons, or	95.4 per cent
Lignite equivalent	4,200,000,000 tons, or	1.3 per cent
Peat equivalent	340,000,000 tons, or	0.1 per cent
Water-power equivalent	10,300,000,000 tons, or	3.2 per cent
Total	319,840,000,000 tons	100 per cent

The second table was compiled by assuming 1 lb. of bituminous coal equivalent in effective energy content to 3.14 lb. of lignite, 2.47 lb. of peat and 0.33 kw.hr.

The reason for the government's change of front is evident from these figures, for there can be little use in trying to save bituminous coal by burning peat when there is 1,000 times more coal available than peat. It must not be assumed, however, that the government has refused to consider all water-power developments; but the greatest caution is advised in weighing the relative merits of coal and water power, and it is emphasized that the decision should rest exclusively upon the actual cost of producing energy by the two methods and not on any sentimental considerations of fuel conservation, for the nation's financial resources are in greater danger than her coal supply.

W. C. L. Eglin

Designer of Philadelphia's Electric System

SIMPLY to design a power plant is one thing—to start with a group of independent plants and mold them into a smoothly working unit is another story. Such a task calls for more breadth of vision and courage to lead the way than is possessed by the average engineer. It is the ultimate achievement in the field of power-plant design, and William C. L. Eglin has made it his life work.

He was born in Glasgow, Scotland, was graduated from the West of Scotland Technological College and was associated with Rankin Kennedy in his experiments on alternating-current generators and transformers. Then, in 1889, at the age of twenty, he came to the United States and was employed by the Edison Electric Light Co., of Philadelphia. While with this company he superintended the electical construction of the first modern central-station plant in Philadelphia. When it became evident that the numerous independent systems in the city would have to be standardized and consolidated, he was put in charge of the work. The different systems were finally organized into the present Philadelphia Electric Co., of which Mr. Eglin is chief engineer.

After this unified system had been established, the next step was to enlarge it, and the most recent addition is the new 180,000-kw. Delaware Station. Mr. Eglin superintended the design of this plant and embodied in its construction a number of rather unusual ideas. He has been a consistent advocate of higher boiler settings, and his design of the settings for the Delaware Station is an interesting story in itself.

Mr. Eglin has long been active in the National Electric Light Association and served as its president from 1908 to 1909; he was especially interested in safety work and industrial relations and brought about the establishment of company sections of the organization during his term as president. He is a fellow of the American Institute of Electrical Engineers and is prominent in the Franklin Institute and the Engineers' Club of Philadelphia.

EDITORIALS

Standard Steam Tables

ONE of the contributors to the discussion of the report of the Committee on Power Test Codes of the American Society of Mechanical Engineers suggests that the Society acquire the copyrights of the authors of the several tables now in use and issue a Standard American Steam Table.

This has already been discussed by the Committee on Power Test Codes, and the individual committee on Definitions and Values has been requested to investigate and report upon the practicability of carrying out the suggestion.

It was proposed that the authors of the existing tables and other authorities upon the subject be requested to confer, with the object of authorizing a table that would serve the common purposes of the mechanical engineer and upon the substantial accuracy of which they could all agree, each reserving his own opinion with regard to the more precise values of the as yet indeterminate properties.

The carpenter and the carpet layer could not wait until all the niceties of metrology had been settled before they could have a two-foot rule and a yardstick to work with. What the engineering profession needs now is a steam table of the two-foot-rule grade of accuracy. It is of more importance in ordinary work that we all measure in the same units than that these units are so very precise. We got along very nicely when everybody used 772 foot-pounds for the mechanical equivalent of the unit of heat. Why should we have three or four different tables because that number of authors prefer 777.54, 777.64, 777.78 and 778, or because one author considers that the tables should be thermodynamically consistent and that another feels that they should accord with the experimentally determined facts?

Some of the tables have columns of values that the others have not, and arrangements, especially of the superheated portions, some of which are useful for one purpose and some for another, but one cannot avail oneself of values given in different tables or of the different arrangements—as Peabody's tabulated values for constant entropy—and check with tables that he prefers to use for other reasons. The tables have different symbols for the various properties, some two symbols for most of them.

There ought to be one table as accurate as the authorities will agree upon—and when a value is determined with sufficient precision that it becomes debatable between the knowing ones, anything within the disputed difference will do for ordinary use—with columns of all the useful properties, with a standard notation, and with all the useful forms of tabulation. This would give the maximum of convenience for use, and one would not have to explain with every report that he made or every paper or article that he wrote whose steam tables he was using. Neither would he have to try a half-dozen tables when checking out his own past work or that of others. The American Society of Mechanical Engineers is the proper body to provide the profession with such a table.

The only arguments that have been urged against it are: First, the encroachment upon the functions of the publishers of the present tables, and the royalties of their authors. This could be met by acquiring their copyrights. Second, the offense to the authors in their deposition as recognized—though competing authorities upon the subject. This could be taken care of by having them all take part in the outlining of the new tables to be published under their joint authority with reservations as to the more precise values. Third, that the publishing of a set of standard tables would crystallize the art, and that nobody would be interested to produce anything better.

We doubt very much if the publication of a standard table, avowedly only as precise as the best knowledge of the day permits, would deter physicists interested in straightening out the inconsistencies and solving the mysteries of steam and other vapors as they approach their critical points, from further efforts, any more than the furnishing of a fairly accurate two-foot rule for common purposes precluded John Brashear from following out the methods of precise measurement which led him to say to the witness who testified that he could measure to the fifty-thousandth of an inch, "Coarse work, my boy, coarse work!"

Limitations in Power-Plant Efficiency

IN ANY power development the ultimate efficiency is measured by the cost of delivering a unit of power at the point of use. A number of the factors comprised in this cost are not of immediate concern to the designing engineer. It is largely influenced, however, by the economic cost of producing a unit of power at the power-station switchboard, which is entirely dependent upon the design of the power station. The unit cost at the power-station switchboard is governed by the thermal efficiency of the power-producing equipment; the fixed charges which are dependent upon the first cost of the power station, and operating labor cost, which is dependent upon the operating convenience of the equipment. It is then desirable to so design the power-producing equipment as to secure the highest thermal efficiency commensurate with reasonable first cost and operating convenience. A fourth and to a large extent a controlling factor in the determination of design is reliability and continuity of operation. Frequently, absolute efficiency in the power plant must to some extent be sacrificed to assure continuity of service.

The system of transferring heat from coal into steam and converting this heat energy into power in a rotative or other motive machine places certain limitations upon the thermal efficiency attainable in a power-producing system. Boilers under ideal conditions may be operated with efficiencies of eighty per cent or even a trifle higher. Steam-turbine generating machinery may have Rankine efficiencies as high as seventy-five per cent and, in combination with condensers, over-all efficiencies of twenty-seven and one-half per cent.

Combining these efficiencies and making a proper deduction for boiler-feed pumps, forced-draft fans and miscellaneous station power and lighting equipment, gives an over-all thermal efficiency as high as twenty or twenty-one per cent. By the use of economizers, air preheaters and other heat-conserving apparatus, even higher theoretical efficiencies may be reached, but with the present cost of fuel the expense of installing such apparatus is frequently not warranted. This efficiency is the limit toward which we may expect actual operating figures to approach. How close the operating figures may come to this limit depends on the excellence with which the arrangement of the equipment and the distribution of heat are designed. In this respect the "Heat Balance Study of Colfax Power Station," by W. P. Gavit in this issue, is an interesting example.

Tendencies in Power-Plant Design

WITH our present methods of converting the energy in coal into electrical power, have we reached the limit of economic efficiency of this process? In 1916 a plant was put in operation having a twenty-thousand-kilowatt unit which had a guaranteed water rate at a fifteen-thousand-kilowatt load of 10.25 pounds, with steam at 265 pounds absolute and 250 degrees superheat at the throttle, expanding down to one inch of mercury. Approximately five years later, the Colfax station of the Duquesne Light Company, described in *Power* April 5 and May 3, and the Delaware station of the Philadelphia Electric Company, described in the leading article in this issue, were put into service. In these stations the steam conditions, as might be expected, are considerably different from those of their predecessor of five years. However, instead of a tendency toward the high pressures and temperatures so much discussed at that time, the reverse is true. Instead of a total steam temperature at the throttle of 656 deg., as in the former, in the two latter installations temperatures of 585 and 576 degrees are used respectively.

In Colfax station a 60,000-kilowatt three-cylinder cross-compound unit is installed, and with steam conditions at the throttle of 280 pounds absolute and 175 degrees superheat and when expanding down to one inch of mercury, a water rate of 10.58 pounds is guaranteed at fifty-thousand-kilowatt load, which is the most efficient rating. In the Delaware station the steam conditions at the throttle are 250 pounds absolute, 175 degrees superheat, and the guaranteed water rate is 10.8 with a twenty-two thousand-kilowatt load on a thirty-thousand-kilowatt single-cylinder unit. Comparing the main units in these three stations they show thermal efficiencies of 25.74 per cent for the high-temperature plant, 25.65 for Colfax and 25.2 for Delaware. Power-plant operation with steam temperatures ranging up around 700 degrees has not been all that could be desired. Experience has shown that it is one thing to design a station to operate at high temperatures and thermal efficiency and quite another problem to operate this same station and keep it in service. The cost of a kilowatt-hour on the switchboard is influenced by other factors than over-all thermal efficiencies and of these the costs of operation and maintenance are not to be neglected. The figures for both Colfax and Delaware indicate a tendency toward more conservative design in order to simplify operation, reduce maintenance and increase reliability of the station. The situation of the plant relative to the coal supply will have an influence on the refinements that are warranted on a cost per unit output on the busbars. If the plant is located at the mouth of a mine, then such refinements as economizers and other heat-conserving equipment may not be justified as was the case in Colfax, whereas, if the plant is some distance from the mines, as is Delaware, and the cost of coal is higher, then they may be justified by the increase in over-all thermal efficiency.

If the present indications count, then the time when steam temperatures in excess of six hundred and fifty degrees is the rule and not the exception is probably not very close at hand. This, then, means that no radical improvements in power-plant efficiency may be looked for beyond those that have been attained in the large well-designed stations at present, unless some new method is developed commercially for converting the heat energy in the coal into electrical power.

To Co-operate with Industry

FOR years the Department of Commerce has served as a repository for a number of unrelated Government bureaus, each doing more or less important work in a restricted sphere, but on the whole out of touch with industry. The machinery for collecting, compiling and making available statistical information has been such as to cause it to lag far behind the need.

Now, with an engineer as Secretary of Commerce, there are indications that the Department will be reorganized to function as its name would imply. Mr. Hoover is determined that it shall be a real aid to industry—not in a regulatory sense, there being other Government agencies charged with that duty—but rather that it shall serve the business of the country much as the Department of Agriculture does the farmer.

In the first place it is planned to regroup the several units so as to prevent, if possible, overlapping; certain bureaus will be made self-supporting, and the activities of those relating to industry will be co-ordinated. Close contact will be established between the department and groups of manufacturers and business men, with a view of studying the economic problems at home and abroad, to make possible prompt and accurate reports of economic tendencies that may serve as a barometer of business conditions, much as the Weather Bureau reports inform the farmer of impending weather conditions.

To accomplish this will require at the start a small appropriation by Congress and the hearty and unselfish co-operation of industrial groups. Mr. Hoover modestly requests only $600,000—a sum, as he points out, to use a military comparison, sufficient only to maintain a brigade of soldiers for a year; yet the return, measured by industrial results, will be many times this amount. Congress, in a spirit of retrenchment, is now holding tightly to the purse strings, but if it is made to understand that business men are solidly behind the request, there is little doubt that the appropriation will be granted.

Of even more importance is the co-operation of industry. When it is appreciated that the Government is endeavoring to assist rather than obstruct or regulate business, it is believed that the plan will have the united backing of industry, with the possible exception of a few interests that, for purely selfish reasons, may refuse to co-operate. General business opinion, however, will ultimately bring them into line.

CORRESPONDENCE

What Caused This Pipe Corrosion?

On page 596 of the April 12 issue of *Power* I read Mr. Forbes' inquiry about the corrosion of the pipe in his overhead coils. I suggest that the cause may be found in the condition of the feed water. Such a condi- as Mr. Forbes relates is frequently noted in plants where the water is treated with compounds of an acid or an acid-producing nature. Further information regarding such cases would be interesting.

Buffalo, N. Y. W. HARRIS DAY.

Some precaution is taken when laying up a boiler for the season, but little attention is given in laying up a heating system. A boiler that is to be cut out for the summer season is generally thoroughly cleaned externally and filled with water to the safety valve; some prefer draining the boiler and closing all valves tight so that no air will circulate in the boiler. If the boiler is only half filled with water when laid up for the season, on examination it will show signs of pitting at the water line in about three months.

Why will not the same thing take place in a heating system that is not thoroughly drained, if air finds its way in through the air vents? Frequently, the valves on the pipe lines leading to the system leak and allow the condensation to drain from a part of the system. If the system is not properly pitched, it cannot be thoroughly drained and the condensation is trapped. The return valves on all radiators should be left opened.

I have had considerable trouble with short horizontal nipples on radiators, and generally on examination I found a considerable amount of sediment mixed with oil, which I believe caused the pitting or corroding. On vertical pipes no sediment will collect. I use sal soda in the boilers and about one week before the heating system is shut off I dissolve and feed three ordinary pails of soda into the boiler that is used with the heating system at low pressure when exhaust steam is not available. In this way the system is thoroughly cleaned and the sediment is blown into the sewer. This system is over twenty years old, and I have had little trouble with the pipes since adopting the cleaning-out method.

New York City. PATRICK MOLLOY.

I have had experience with overhead radiator pipe coils in factories using a vacuum-heating system, similar to that mentioned by O. R. Forbes, in a recent issue of *Power*. I do not know of any special remedy to entirely prevent pitting, grooving and erosive thinning of the pipes, but it can be somewhat reduced. If the thinning is general along the pipe, it may be caused by galvanic action set up by chemicals in the feed water carried through the pipes with the steam. As there are always more or less air leaks in the system, considerable air will accumulate when the steam is shut off, even for a few hours. The air flows along the top of the pipe and, when saturated with moisture of an erosive character, attacks the slightest abrasions in the pipe, especially steel pipe, and a hole will soon appear.

Considerable water hammer may occur in the pipes if they sag in the center, forming a pocket for the accumulation of water and thus preventing the air from passing to the vacuum pump. Pipe coils should pitch a little lower at the return end than at the steam end so that the condensate and air can pass through them.

After a pipe has become corroded in service and dried out, air having come in contact with the corroded part, the erosive action of steam, air and water, when again admitted, will be much more rapid than if the pipe had not been dried out or exposed to the air.

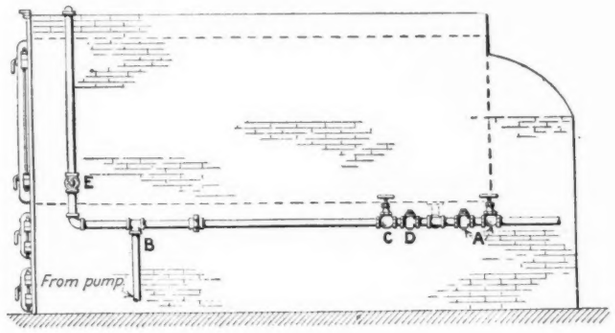
Mr. Forbes does not state what kind of traps are used. If high-pressure traps, with live steam in the coils, take care of the condensate from a number of radiators instead of individual return radiator traps, a large trap will not free the coils from air, even though it discharges into a vacuum return main. But where high-pressure live steam is used in some parts of the system and low or exhaust steam on other parts, all discharging in the same return line, the traps cannot be dispensed with. Best results are obtained by keeping the live-steam pressure so low that it will just do the required amount of heating and no more. Where individual return-radiator traps are used and properly adjusted to relieve the coils of air, and the vacuum pump is large enough to maintain 15 to 20 in. of vacuum at the pump, then the air and vapor and water will be drawn out of the coils.

Water hammer, air leaks and three steam pressures in one return pipe caused the most of my trouble in one plant with 400,000 sq.ft. of low pressure radiation, besides the high-pressure system and manifold coils. I dispensed with all steam traps as far as possible except high and low vacuum traps on long return lines, and in some places installed high-pressure radiator return valves on the separate high-pressure radiator heating coils; but on manifold coils using exhaust from an engine part time and live steam at times, the amount of condensate was too great for any group of radiator return valves to relieve, and a trap had to be used. This was provided with a bypass valve to open at times when starting allowed the air that had accumulated in the coils over night to be blown out. R. A. CULTRA.

Cambridge, Mass.

Blowoff-Pipe Arrangement

Sometimes it is desirable to have the boiler blowoff pipe arranged to be cleaned of mud or scale by means of a counter pressure. Such an arrangement is shown. At *A* are the blowoff valves; *B* is the feed-water supply pipe from the feed pump. Two valves *C* and *D* are used between the pipe *B* and the blowoff connection to the boiler, as the valve *C* will not remain watertight, but is



PIPING ARRANGEMENT FOR CLEANING BLOWOFF PIPE

a protection to the valve *D*. Feed water goes to the boiler through the valve *E*, the usual pipe connection, check valve, etc.

Should the blowoff pipe become clogged between the valves *A* and the boiler, the full pump pressure can be exerted on it by opening the valves *C* and *D* with a good chance of loosening up the sediment which may be the cause of the trouble. JAMES E. NOBLE.

Portsmouth, Ont., Canada.

Saving by Proper Ash-Handling Equipment

My attention was called to an article beginning on page 581 of the April 12 issue, entitled "Saving by Proper Ash-Handling Equipment," by Hubert E. Collins.

I am unacquainted with Mr. Collins, and I do not pose as an authority on ash-handling systems, but a few years ago I was given the task of finding out, by investigation, for one of the stationary plants of the New York Central R.R., just how much a steam-ejector system for handling ashes would save over their present system of handling ashes by wheelbarrow and truck, and I found as the result of this investigation that there would be no savings; they are still using their present system—by hand.

Let me point out where Mr. Collins is wrong. He says, in the first instance, that the saving is $1,297 a year, and he derives this saving because he eliminates all labor, including the carting away of the ashes. May I inquire what becomes of the ashes after they are deposited in the bin by the ejector system? Do they evaporate into nothingness?

The foregoing holds true in both the other instances that he mentions, for in neither case does he make any provision for carting away the ashes. In fact, he says on page 582, "One fireman on watch was able to remove all the ashes without help . . . for sweeping the overflow into the intakes where it disappears out of his way." Where do the ashes disappear to?

As to the steam cost of removing the ashes from in front of the boilers to the storage bin, this is not a small item, as Mr. Collins states, but on the contrary it takes a certain number of pounds of steam to move 100 lb. of ashes a distance of 100 ft. This really amounts to quite an amount of steam when properly figured out.

In brief I think that Mr. Collins' statements are misleading, to say the least, and when the cost of removing the ashes from the bins is added, there will be found no actual saving. C. F. HERINGTON.

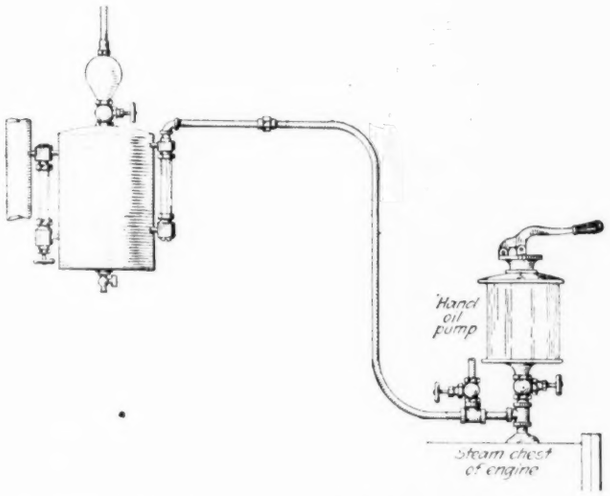
Canton, Ohio.

Another Lubricator Kink

On page 638 of the April 19 issue of *Power*, Mr. Weiss illustrates a "lubricator kink," which, although good, is not as good as it might be. If he had left the drain cock at the bottom undisturbed and connected the pipe from the tee to the top of either the lubricator or to the gage glass, he would have had a much better outfit. Its operation would then consist of pumping the oil, which could be done without even stopping the feed. It is well, however, to stop or check the feed while filling, as the impulses of the pump are liable to soil the sight-feed glass by spurting drops of oil against it on leaving the nozzle.

With the arrangement shown, the water will give place to the oil by passing up through the condenser and pipe and off through the engine. This saves all the work and mess incident to the openings, draining and closing of the lubricator. Also, if the lubricator should run dry and become hot, this arrangement will fill the condenser chamber and pipe with water for immediate use.

A kink that may be of use to some is an effective way of repairing leaky filling plugs. With a soldering



SUGGESTED CHANGE IN LUBRICATOR FILLING PIPE

iron run a ring of solder around the plug where it forms the seat. The size and shape of the plug will indicate how much solder should be put on, but put on enough. Then with a file (use a safe edge to protect the threads) dress the solder to an approximate fit. The plug can then be screwed into place, when the high spots will be spotted and can be scraped. Continue this operation until a fit is obtained, and the plug will be as good as new. B. E. ECKARD.

Wadsworth, Ohio.

What Caused the Boiler Heads to Corrode?

Referring to the article "What Caused the Boiler Heads to Corrode?" published in *Power* Dec. 7, 1920, and the answer thereto in the March 8, 1921, issue, I wish to call attention to an article relating to this explosion, that appeared in the *Zeitschrift des Vereins deutscher Ingenieure,* March 12, 1921. In this article quotations of the report of the boiler inspector are given which supplement the information contained in the letter of Dec. 7.

It may be of interest for readers of *Power* to know that according to this supplement the fracture did not occur in the seam, but in the knuckle of the head, and that the feed water had not shown any properties to justify the assumption of a chemical action or corrosion. On the contrary, it is stated that the boiler was free of defects and without the slightest sign of corrosion and that the surfaces near the water line especially, were in such a condition as to give them the appearance of new material. The material in the crack itself was not corroded; on the contrary the fracture was sharp.

These statements certainly do not sustain the assumption that corrosion caused the rupture or that caustic soda was a probable cause of it. H. KRIEGSHEIM.

New York City.

Boiler-Feed Pipe-Scaling Trouble

The following trouble was experienced while operating three water-tube boilers. Each was in 24-hr. service seven days a week and was cleaned every eight weeks, at which time we always ran a rod through the internal feed pipes which projected through the front heads into the drums a distance of about five feet. We never found any great amount of scale in the internal feed pipes and did not expect that the external feed pipes, which were of brass, would scale to any extent,

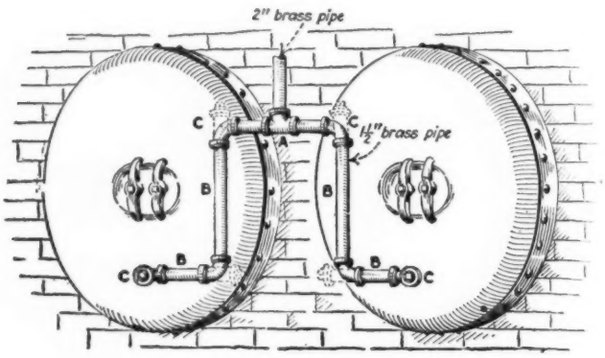


FIG. 1. ORIGINAL FEED PIPE ARRANGEMENT

as we were unable to get the feed-water temperature much above 150 deg.

One morning, on my arrival at the plant, I found the night engineer having trouble getting water into No. 2 boiler. After looking over all valves, etc., I concluded that the feed pipe was obstructed. We changed boilers and dismantled the feed pipe, which was arranged as shown in Fig. 1.

The 2-in. pipe was free of scale down to the tee *A*, from which 1½-in. branches were extended to the drums. From the tee *A* to the inside of the heads both of these pipes *B* were almost full of a sand scale, there being only about a ⅜-in. opening in each pipe. The internal feed pipes had very little scale in them. The elbows at *C* were replaced with tees, and thereafter when cleaning boilers we removed the plugs from the tees and ran a pipe through the feed pipes and cleaned them thoroughly.

At the time of this occurrence the boilers had been running about six years and had never before developed any such trouble. About the same time we began to

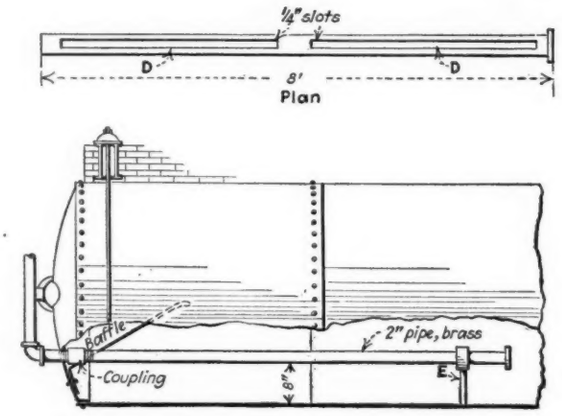


FIG. 2. SLOTTED INTERNAL FEED PIPE FOR DISCHARGING WATER IN THIN FILM

experience trouble with scale forming on the bottom of the drums directly under the feed pipe outlet. During the run of eight weeks the scale would form to a thickness of about ½ in. and was very hard.

I then devised the internal feed pipes shown in Fig. 2. I took 2-in. brass pipes, 8 ft. long threaded at both ends, and cut a slot *D* ¼-in. wide in the top of the pipe, leaving a bridge of 3 in. midway of the length and also one extending to within 3 in. of each end. One end of the pipe was capped, and the other end was coupled to the feed-pipe nipples coming through the front head of the drum. A support *E* at the inner end holds the pipe level.

As we had good feed-water regulators, which gave a constant feed, I figured that there would be a very thin film of water the full length of the slots and that the water would flow out of the slot over and down both sides of the pipes and become heated to the temperature of the water in the drums before reaching the shell, thereby releasing the scale-forming matter in such shape that the circulation would carry it to the rear of the boiler.

After installing these pipes, the boiler was run for eight weeks and then upon inspection no scale was found on the bottom of the drums. The two other boilers were then equipped in the same manner, and during the next three years that I remained at the plant no trouble was had with scale on the drum sheets. My theory is that, with the old piping, the water issuing in mass from the end of the pipe, discharged directly on the drum sheet, but with the slotted pipe they acted as an instantaneous heater, on account of the water being fed in a thin film. The scale in the external feed pipes was caused, I believe, by the water passing slowly through the branch pipes, which were close to the drum heads and were thereby heated sufficiently to cause scale formation. C. A. GREEN.

Cleveland, Ohio.

Data on Motor Operation

Referring to Howard D. Matthews' reply (*Power*, Feb. 22, page 322) to Mr. King's inquiry in the Jan. 18 issue, page 116, with regard to overload-relay setting for induction motors to give protection against single-phase operation, the following may be of interest:

In the case of hand-operated starting compensators it has not been customary to connect the relay coils in the starting circuit, because the majority of compensators do not trip free from the handle, and the operator naturally does not release the handle until he has moved it from the starting to the running position. Therefore, even if the relays did function on the starting side, they could not disconnect the motor until the handle had been released.

The ordinary type of overload time-limit relay, even if set to operate on 25 per cent overload and adjusted as to time so that it will carry the overload long enough to allow the motor to come up to speed, would probably continue its upward movement and trip the breaker, even though the current should drop as low as 50 per cent of full-load value. The reason for this is that, with a given current, the upward pull on the plunger varies approximately inversely as the length of the magnetic air gap, and when the plunger has started to move upward, the air gap is progressively reduced, and less current is needed to keep the plunger moving and eventually to trip the breaker. This is another reason why it has not been usual to connect the overload relays in the starting side on hand-operated compensators.

There is now available an oil-immersed push-button-operated automatic compensator, which is being extensively used in place of hand compensators and is provided with an overload relay having new characteristics. It is of the "non-creeping" design, and for a given current the pull on the plunger remains constant throughout its working stroke. This relay is connected in the starting side and can be adjusted to trip on 25 per cent overload, and even if the plunger has almost completed its stroke, it will drop back to its original position on a very small reduction in current. For instance, if the relay is set to operate on 100 amperes, and the current drops down to 90 amperes just before the relay trips, the plunger will drop back to its normal position. This arrangement, therefore, gives perfect protection against single-phasing.

Another device now available for small motors that are started directly across the line provides push-button control and is equipped with thermo-expansive overload relays that may be adjusted for 25 per cent overload and have about the same operating characteristics as the dashpot relay referred to.

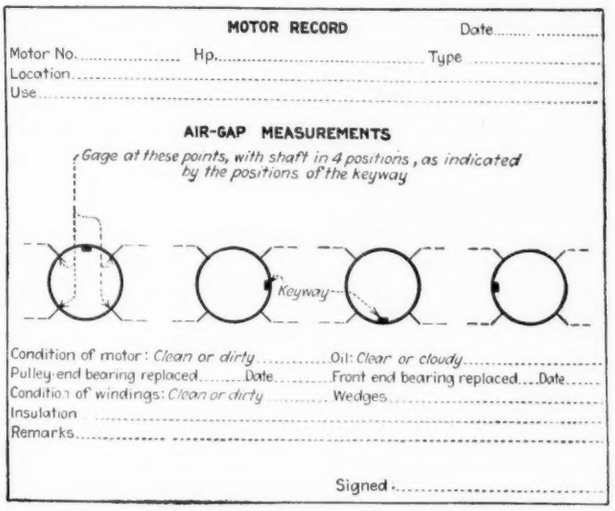
R. G. WIDDOWS.

New York City.

Referring to Mr. King's article on induction-motor operating troubles it is the writer's opinion that, for proper protection against single-phasing, the overload relays on the compensator should be connected in the running side only, and set for not more than 20 per cent overload. The time setting should be long, so as to avoid tripping on sudden overloads of short duration. In cases where the motors are too large for the work the relays may not trip if set for a certain overload on the motor, even though the latter be running on single phase. Care should be taken in this case to set them about 20 per cent above the actual load the motor is required to carry, regardless of its rating. A close relay setting with long time limit will afford the proper protection against single-phasing, for the opening of one line will add about 70 per cent to the load on the remaining phase and trip the relays on that phase.

Correctly proportioned starting fuses should protect the motor against attempts to start it on single phase. Fuses are recommended in all cases, but particularly when the motors are not within sight of the person who is attempting to start them. They not only serve to protect the motor, but provide means to disconnect the motor and its starting equipment from the line, so that it can be worked upon with safety.

Concerning the lubrication of motors I think it is safe on standard motors to use the same grade of oil for all sizes and speeds, for high-speed motors usually have smaller shaft diameters than low-speed motors,



MOTOR RECORD CARD FOR RECORDING RESULTS OF INSPECTION AND REPAIRS

and the actual linear velocity at the bearing surface does not change very much.

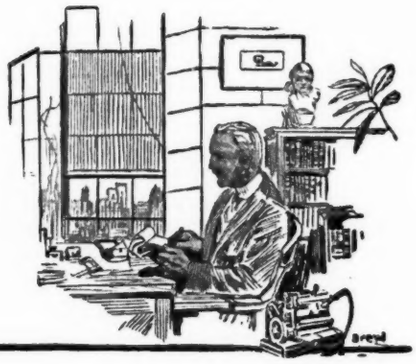
Keeping the motor clean is a very important point in avoiding insulation failures. Frequent and even daily inspection is of great importance, and under special conditions, as in plants manufacturing textiles or pulverized substances, it may be necessary to blow the motors out daily with compressed air. Under these conditions careful attention should be given during the inspection to the condition of the bearings, and it may be necessary to oil them considerably more frequently than in most plants, for the dust or lint deposited on the bearings and oil gage draws the oil out by capillarity.

It is most advisable to establish some kind of a system to record the air-gap dimensions on each motor at regular intervals, say once a week. The record may be kept on cards, one for each machine, and the form suggested is given in the illustration. Air-gap measurements should be taken with the shaft in four positions, 90 deg. apart, as indicated on the card by the position of the keyway. Four measurements should be taken for each shaft position and marked opposite each point, as shown on the card. Any motor whose air gap proves below safe limits, say 0.005 in. to 0.008 in., should have its bearings renewed.

If the foregoing indications are carefully followed, there should be no reason why the rewinding cost for an industrial concern should not be materially reduced.

Meriden, Conn. H. A. G. GEIS.

INQUIRIES OF GENERAL INTEREST



Providing for Corrosion Around Handhole—What can be done in case the inside of a boiler plate is too much corroded around the edge of a handhole opening to obtain a tight gasket joint? E. M.

Use a larger handhole cover and gasket to reach far enough back from the edge of the opening to make a joint with uncorroded part of the plate. If that cannot be done it will be necessary to rivet a reinforcement around the opening placed on the inside of the boiler and calked around the periphery, with a suitable margin for a gasket bearing next to the opening.

Necessity for Excess Air—Would it not be better to dispense with all excess air admitted to a boiler furnace? J. W. S.

Excess air is the amount of air admitted in excess of the amount of air theoretically required for complete combustion. But to insure complete combustion and give each atom of carbon and other combustible elements opportunity to combine with the necessary amount of oxygen to effect complete combustion it is necessary for the air supply to be in excess of the theoretical requirement. When only enough excess air has thus been supplied to obtain a high percentage of CO_2 in the flue gases the heat obtained from the combustion exceeds the heat that would be obtained from imperfect combustion with no excess air by an amount considerably greater than the loss incurred from such excess air.

Cause and Loss from Cylinder Re-Evaporation — What causes re-evaporation during expansion of steam in an engine cylinder; and why is re-evaporation that results in higher m.e.p. to be considered as detrimental to economy of the engine? W. T.

After cutoff has occurred, the pressure falls and water present in the cylinder begins to re-evaporate as soon as the lowering pressure due to expansion falls below the pressure corresponding with the temperature of the water in the cylinder. The latent heat required for the re-evaporation is partly obtained from the water itself, but is mainly obtained from the cylinder walls, and the greater the re-evaporation the more heat must be given to the walls by the steam supplied during admission on the succeeding stroke. Except for the small amount of work done by the re-evaporated steam, the heat thus given up to the walls is discharged during exhaust, and there is less work obtained out of the re-evaporation than if the heat was retained in the admission steam for its expansion from the initial pressure.

Speed Regulation of Differential-Compound Motors—Why is a direct-current motor with a differential series-field winding said to be unstable? J. H. B.

This motor is said to be unstable for two reasons: First, because its speed fluctuates considerably with variations in the load, and secondly, because of its liability to flash over on sudden overloads. The speed of a differential-compound motor rises with the load because the series field weakens the shunt field. But as the load is applied to the motor it must first slow down in order to draw more current from the line to supply the increased torque called for. When the speed has dropped sufficiently the current drawn by the motor will have increased, the series field will therefore decrease the field strength and the motor will have to speed up again to generate the proper amount of counter-electromotive force For every variation in load there is, therefore, a double variation in speed.

The differential motor is, furthermore, subject to flash-overs on sudden and heavy overloads, because the field is weakened just when the motor is called upon to supply a heavy torque. It therefore draws a very large current from the line, which sometimes causes a flash-over.

Pumping Ammonia From Coils—Is it possible to pump ammonia from freezing coils by creating a vacuum on the compressor while the freezer temperature is 10 deg. below zero? P. S.

If the temperature of the freezer is 10 deg. below zero, the liquid ammonia in the coils cannot absorb heat from the freezer and boil unless the coil temperature is 10 degrees or more below zero. The pressure of ammonia vapor corresponding to a temperature of 10 degrees is 23.75 lb. If the compressor is started, the coil pressure will be 23.75 lb. If the expansion valve is throttled so that little ammonia enters the coils, the suction of the compressor will remove part of the ammonia vapor, reducing the pressure. But as the pressure is lowered, the boiling temperature also drops, and if ammonia liquid is present, it will evaporate at the lower pressure, giving a lower coil temperature, although the freezer may still be at 10 degrees. If only ammonia vapor is present in the coil, the reduction of pressure will tend to superheat the vapor.

Quality of Steam Discharged Through Reducing Valve—Would steam at the absolute pressure of 300 lb. per sq.in. and containing 2 per cent moisture be superheated when passed through a reducing valve and reduced to 250 absolute? C. S.

The initial steam would not contain sufficient heat to be in a superheated condition for the reduced pressure. The latent heat of evaporation at 300 lb. absolute is 811.3 B.t.u., the heat of the liquid is 392.7 B.t.u. and the total heat per pound of the initial steam would be $392.7 + [811.3 \times 1 - 0.02] = 1{,}187.77$ B.t.u. above 32 deg. F. At the pressure of 250 lb. absolute the total heat in a pound of dry saturated steam is 1,201.5 B.t.u. above 32 deg. F. or $1{,}201.5 - 1{,}187.77 = 13.73$ B.t.u. more than the heat contained in the initial steam. Hence the steam would contain moisture. A pound of dry saturated steam at 250 lb. absolute contains 375.2 B.t.u. heat of the liquid and 826.3 B.t.u. as latent heat. Hence when there is 13.73 B.t.u. less than dry saturated steam at 250 lb. absolute the quality would be

$$\frac{(826.3 - 13.73) \times 100}{826.3} = 98.3 \textit{ per cent dry}$$

that is, the steam at 250 lb. absolute would contain 100-98.3 = 1.7 per cent moisture.

[Correspondents sending us inquiries should sign their communications with full names and post office addresses. This is necessary to guarantee the good faith of the communications and for the inquiries to receive attention.—Editor.]

Standard Specifications for Boiler Settings

The following standard specifications for the setting of boilers have been presented by Commercial Committee of American Boiler Manufacturers' Association.

Water-Tube Type

Foundations: The foundations up to the floor line shall be provided by the purchaser in accordance with drawings made by the contractor. The purchaser assumes responsibility for proper foundations. The contractor does not assume any responsibility for stoker foundations as same are taken from drawings prepared by the stoker manufacturer.

Walls: The side walls of the boiler setting will be..... inches thick, the rear wall.....inches thick, and front wall .....inches thick. The firebox sides of the furnace, front wall, bridge wall and first pass, are to be of No. 1 quality of firebrick. The firebrick lining through the first pass is to be 9 in. thick—balance of firebrick lining to be 4½ in. thick and made of No. 2 quality of firebrick. All common brick used in this setting to be hard-burned and of good quality. No small pieces or chips are to be packed into any wall. All brickwork in walls to be bound by a course of headers at every fourth row.

The mortar to be used shall be composed of one part portland cement, two parts lime and six parts of sand. The sand must be sharp and free from loam.

The cement and sand to be thoroughly mixed dry, then added to and thoroughly incorporated with the lime and enough clean water to form a stiff paste, and to be used promptly.

Any special brick or tile required by the type of stoker that purchaser selects, must be furnished and delivered on the boiler-room site without cost to the contractor.

The top of the boilers will be covered in the manner shown by the contractor's drawings. All brickwork is to be done in a first-class and workmanlike manner.

This proposal is based upon the following prices and conditions.

PRICE OF MATERIAL

Common hard-burned brick @ $	per M f.o.b.
No. 1 firebrick	per M f.o.b.
No. 2 firebrick	per M f.o.b.
Tile	each f.o.b.
Tile	each f.o.b.
Tile	each f.o.b.
Tile	each f.o.b.
Tile	each f.o.b.
Cement	per sack f.o.b.
Lime, hydrated	per sack f.o.b.
Lime, lump	per cwt. f.o.b.
Sand	per ton f.o.b.

PRICE OF LABOR

Masons @ $	per hour
Helpers	per hour
Mason foreman	per day, extra
Helper foreman	per day, extra

Conditions: If the cost of material and labor is greater than the prices above quoted, contractor is to be reimbursed for the extra cost, and if prices are lower purchaser is to be credited accordingly.

The boiler is/are to be erected on.....floor. Floors in boiler room to be completed before contractor starts work, or a temporary floor built of scaffold plank laid close together at expense of purchaser.

Water to be furnished contractor in boiler room and free of cost.

The contractor shall be furnished suitable space adjacent to the work for placing any apparatus or material required under this proposal, and the boiler contractor or mason contractor shall be allowed free access to the work at all times for their men and material.

Suitable roadway shall be provided by purchaser to site of erection, for such material as will be necessary to haul to job.

If there be a railroad siding located on the grounds where this work is to be performed, the contractor is to have free use of same for the handling of any material that may arrive by car.

The contractor shall not be liable for demurrage charges on cars of material that accrue before cars have been actually placed for unloading in a suitable place within 100 ft. of site of erection. All demurrage charges accruing prior to 48 hours after placing cars as herein provided shall be borne by the purchaser or others than the contractor.

If this work is done during cold weather, and heat shall be necessary in order to continue work and avoid delay, the heat must be furnished free of cost to contractor.

This proposal does not contemplate extra or overtime work.

The contractor is not responsible for cracks or other troubles that may develop in the brick setting after acceptance, which must take place on completion of the brick work.

Return-Tubular Type

Foundations: The foundations up to the floor line shall be provided by the purchaser in accordance with drawings made by the contractor, and the space between the walls of the foundation is to be covered over with a 4-in. slab of concrete. The purchaser assumes responsibility for proper foundations. The contractor does not assume any responsibility for stoker foundations as same are taken from drawings prepared by stoker manufacturer.

Walls: For boilers 60 in. in diameter and larger the side walls are recommended to be 22½ in. thick and rear wall in all cases 18 in. thick. For a battery setting, the center or division wall is recommended to be 30 in. thick, and the bridge wall 27 in. thick.

For bituminous coal such as obtained in the Middle West, we recommend 14 in. from bridge wall to shell of boiler.

The side walls in "bracketed" type of settings shall be carried three courses above bearing part of the bracket.

All parts of the setting exposed to the products of combustion shall be lined with firebrick. The lining in the firebox to be 9 in. thick and carried up to a height of 12 in. above the bottom of the boiler shell. Balance of the lining to be 4½ in. thick. All lining in the firebox where 9 in. of lining is used to be No. 1 quality to the back of the bridge wall—balance of the lining throughout the setting to be No. 2 quality.

The top of the boiler shell is to be covered over with one course of common hard burned brick of good quality, laid on edge and so as to form a one-inch air space between boiler shell and under side of this arch.

The blowoff connection is to be protected from the fire by a firebrick column about 13 x 13 in., V-shaped, and same carried up close to bottom of boiler shell, and to be made of No. 2 quality of firebrick.

All common brick used in this setting to be hard-burned and of good quality.

All brickwork to be done in a first-class and workmanlike manner, and every fifth row to be a header row. The distance between rear head of the boiler and the inside of the rear wall is to be not less than 28 in. on boilers 72 in. diameter or larger.

This proposal on the above brickwork is based on the following prices and conditions.

(The rest of this form is identical with that for water-tube boilers.)

Chicago Section A. S. M. E. Elects Officers

The Chicago section of the American Society of Mechanical Engineers held its last meeting of the year on May 10 at the City Club. Reports were heard from the various officials and local section committees. The membership committee reported 107 new members and applications, with the hope that the total would be increased to 150 before the end of the present year. Herbert F. Philbrick, the retiring chairman, gave a brief address on "Education," and plans for the spring meeting were presented by the chairman of the various committees.

The following officers were elected for the coming year: David Lofts, chairman; Horace Carpenter, vice chairman; J. D. Cunningham, secretary and treasurer; F. R. Wheeler and J. C. Peebles, members of the executive committee.

As a closing feature O. B. Zimmerman, research engineer for the International Harvester Co., presented some motion picture reels dealing with power on the farm.

Death of George J. Foran

George Jesse Foran, the manager and chief engineer of the condenser department of the Worthington corporation, died on May 12 at the age of 59. He had devoted the greater part of his life to the development and sale of steam pumps and condensing apparatus. He was born in Boston and as a boy studied in the schools of that city. He studied also in the Wesleyan Academy at Wilbraham, Mass., and in 1883 was graduated from the Massachusetts Institute of Technology in the department of mechanical engineering with the degree of Bachelor of Science. For his graduation thesis he prepared a history of the art and design of pumping machinery, in which he had taken a special interest. Shortly after his graduation he took a position with the Deane Steam Pump Co., of Holyoke, Mass., and after a few short months in the shop was sent to the company's Boston office. Three years later he became an engineering salesman with the George F. Blake Manufacturing Co., later serving as consulting engineer to the president and treasurer.

GEORGE J. FORAN

Both of these companies were consolidated in 1901 into the International Steam Pump Co., which was later succeeded by the Worthington Pump and Machinery Corporation. In 1901 Mr. Foran came to New York as manager and chief engineer of the condenser department, and he held that position up to the time of his death.

During the war he was on the committee for condensing apparatus of the United States Shipping Board and War Industries Board, and as chairman of the American Engineering Service of the old Engineering Council handled personnel matters between the departments of the government and the four national engineering societies. He joined the American Society of Mechanical Engineers in 1887 and was chairman of the condenser and heater section of the society's power test code committee.

Metropolitan Section, American Welding Society

At the monthly meeting of the New York Section of the Welding Society, which was held at the Engineering Societies Building on May 17, an interesting paper was read by William Scheustrom on the welding of oil-storage tanks by the electric-arc method. The speaker illustrated the paper with a number of photographs showing storage tanks in process of erection. The method of arc welding was thoroughly discussed, and its advantages over the usual riveted joints were emphasized. According to Mr. Scheustrom the loss due to leakage in riveted tanks runs from 2 to 6 per cent, the latter covering tanks without gastight covers. The welding of the plates, including the making of gastight covers, eliminates this enormous waste. It is estimated that the saving in leakage will pay 40 per cent of the cost of the tank during its life, which is estimated to be 20 years. The speaker, while laying stress on the oil-storage tank, declared that there was no reason why steel tanks of all descriptions should not be welded in the field. The cost of welding would apparently be less than that of riveting, as it is possible for a workman to weld four feet of seam per hour, using a current value of from 120 to 140 amperes, depending on the thickness of the plate to be welded. A paper on the welding of locomotive cylinders with Tobin bronze, by J. T. Paight, of the N. Y., N. H. & H. R.R. was read. Owing to the author's absence no extensive questions were brought up. Mr. Paight described in his paper the process followed in welding locomotive cylinders with Tobin bronze. He claimed that it is far superior to cast iron or steel welding, and unlike those welding agents, no cylinder distortion occurs as no preheating is required.

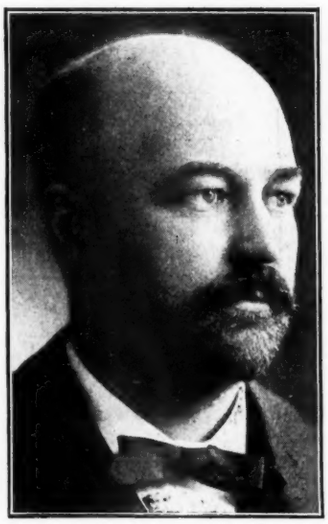
In presenting a paper on the welding of oil-engine cylinders, the author, A. F. Keogh, related an experience in welding a fractured cylinder.

A. Sorge, Jr., Dies

A. Sorge, Jr., well-known among mechanical engineers in the Middle West, died suddenly on the morning of May 5 in Chicago. For twenty-five years he had been general Western representative of the Harrison Safety Boiler Works, now known as the H. S. B. W. Cochrane Corporation.

Mr. Sorge was born at Hoboken, N. J., Sept. 28, 1857. He graduated from the Hoboken high school at the age of fourteen and within the next four years secured a degree in mechanical engineering from Stevens Institute. For a few years he taught the subject that he had studied and served in a consulting capacity for several concerns. Finally settling in Rochester he entered into a general machine-shop business, and in his consulting engineering work, which he continued, was in close relation with George Selden, of early automobile fame, and Mr. Eastman, of the Kodak company that now bears his name. Some years later Mr. Sorge returned to New York to engage in expert work in connection with numerous inventions and patent suits. In 1894 he went to Chicago as superintendent of the Frazer & Chalmers Co. and early in 1896 became associated with the Harrison Safety Boiler Works, of Philadelphia, as Central Western representative; this was later extended and he was made general Western representative.

Mr. Sorge was an engineer of marked ability with an inventive turn of mind. About the year 1898 he carried on extensive experiments in the line of water purification and developed what has since become the Sorge-Cochrane hot process system of purification of water for boiler feed and other purposes. In 1901 he brought out a device for draining oil separators under vacuum, known as the Sorge registering drainer, and five years later the well-known Sorge cast-iron exhaust head. During 1909 and 1910 he developed a steam regenerator for introduction between reciprocating engine units and low-pressure steam turbines. This apparatus was patented and sold under the name of the American Regenerator Co.



A. SORGE, JR

Throughout his long sales experience Mr. Sorge gave much time and study to power-plant installations. In high-pressure steam lines particularly he had worked out a system of reducing sizes materially, offsetting this by the introduction of large receiver separators immediately at the throttle of the prime mover. His plan reduced the cost of the pipe lines and covering, eliminated vibration and practically did away with a drop in pressure between the boiler header and the outlet of the separator.

Mr Sorge was a charter member of the American Society of Mechanical Engineers and was for a number of years a member and secretary of the American Foundrymen's Association. He was also a member of the Western Society of Engineers and the Engineers Clubs of New York and Chicago

Report on Efficiency Tests of a 30,000-Kw. Steam Turbine*

During 1920 three 30,000-kw. G. E. turbines were installed at the Fifty-Ninth Street power station of the Interborough Rapid Transit Co., New York City, complete tests upon one of which form the subject of this paper.

These turbines are of the straight Curtis impulse type, having 20 pressure stages, each pressure stage consisting of only one velocity stage. The normal steam pressure at the throttle is 225 lb. abs., the steam being superheated 150 deg. F. and exhausted into a vacuum of 29 in. The speed is 1,500 r.p.m. In addition to the main or primary steam inlet, a secondary valve is provided that opens after the load reaches 24,000 kw. and enables the turbine to carry 35,000 kw.

The turbine tested is pictured on the Powergraph page in this issue, together with its condenser. The unit was installed on a structural-steel foundation incased in concrete,

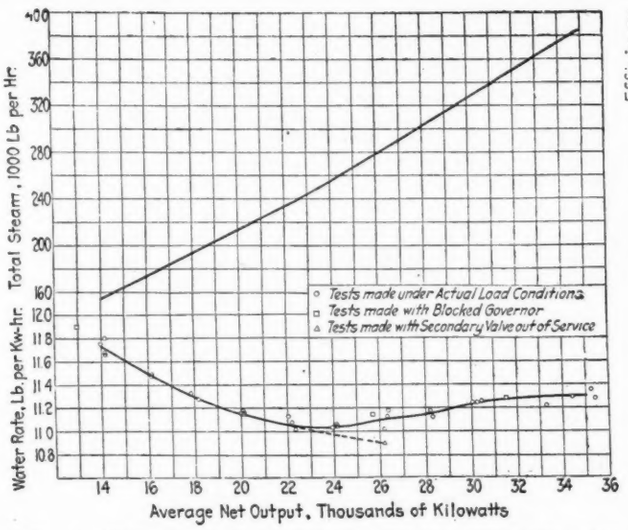

Water Rate, Lb. per Kw-hr. Total Steam, 1000 Lb per Hr.
Average Net Output, Thousands of Kilowatts
Tests made under Actual Load Conditions
Tests made with Blocked Governor
Tests made with Secondary Valve out of Service

FIG. 1. WATER-RATE CURVE AND WILLANS LINE FOR 30,000-KW. TURBINE

Steam pressure, 225 lb. abs.; superheat, 150 deg. F.; vacuum, 29 inches, referred to a 30-in. barometer; water-rate factor, 0.985. Curve based on tests Nos. 10 to 44, inclusive (excluding special tests with blocked governor and test with secondary valve out of service).

which is plainly visible in the illustration. An interesting feature of the structural design is the use of a special set of spring supports for the condenser, in order to obviate the necessity for an expansion joint between the turbine outlet and condenser inlet. Each spring support consists of powerful helical springs mounted on top of a hydraulic jack, the object of the jacks being to facilitate the adjustment of the load on the springs. It is also possible to measure very accurately the stresses in the steam connection between the turbine and condenser, from the oil pressure in the jacks.

A heat-balance connection is provided on the turbine in the form of an inlet valve to the sixteenth stage, through which any excess steam exhausted by the steam-driven auxiliaries and not required for feed-water heating, is expanded down to condenser pressure in the last stages of the turbine.

Most of the tests were of three hours' duration. With the exception of a few special tests, the turbine was operated under normal conditions in so far as type of load was concerned. The load was controlled from the switchboard through the remote governor-control system provided for that purpose. This method of controlling the load subjected the turbine to the full swings of the railroad load.

The performance of the turbine is shown graphically in Figs. 1, 2 and 3. Fig. 1 shows the water-rate curve and Willans line for the turbine. Fig. 2 gives the thermal and Rankine cycle efficiencies. From these curves it will be seen that the lowest water rate obtained while operating under normal conditions was 11.03 lb. per kw.-hr., while the highest Rankine and thermal efficiencies obtained were 75.5 per cent and 25.0 per cent, respectively.

In order to determine the effect of the swinging load on the steam consumption, four tests were conducted with the

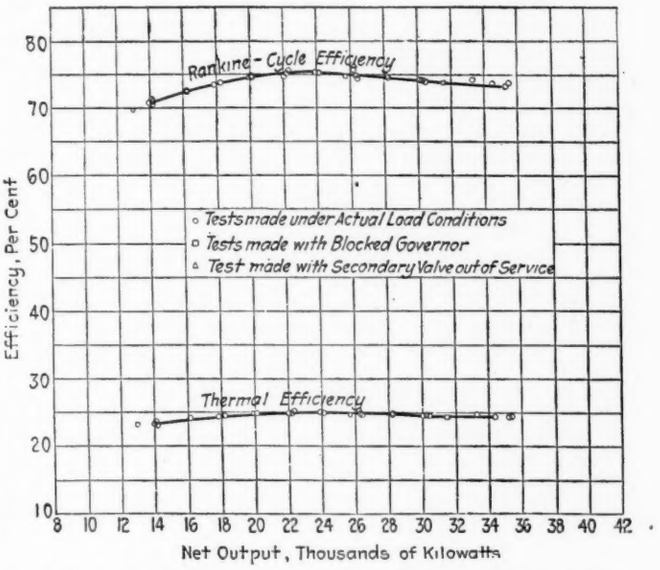

Efficiency, Per Cent
Rankine-Cycle Efficiency
Tests made under Actual Load Conditions
Tests made with Blocked Governor
Test made with Secondary Valve out of Service
Thermal Efficiency
Net Output, Thousands of Kilowatts

FIG. 2. RANKINE-CYCLE AND THERMAL EFFICIENCY CURVES FOR 30,000-KW. TURBINE

Steam pressure, 225 lb. ab.; superheat, 150 deg. F.; vacuum, 29 inches referred to 30-in. barometer.

governor blocked so that the unit operated under a steady load. There was practically no improvement in the efficiency under the steady-load conditions at the loads selected for these tests. When the turbine is operating under normal conditions and carrying loads from 22,000 kw. to 25,000 kw., the secondary valve is continually opening and clos-

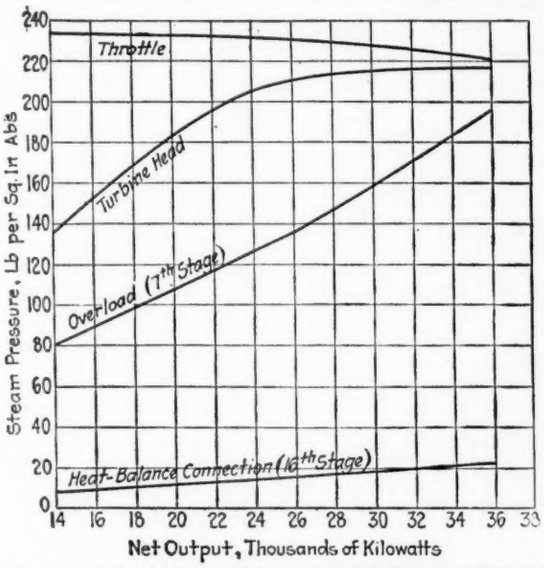


FIG. 3. VARIATION OF STEAM PRESSURE WITH THE LOAD AT VARIOUS POINTS THROUGHOUT THE TURBINE

ing, which no doubt reduces the economy somewhat. The test indicated by one small triangle in Fig. 2 was run with the secondary or overload valve closed and out of commission, while the load was adjusted so that the primary valve was wide open. As is to be expected, the lowest water rate was obtained while operating in this manner. Since the completion of these tests the governor cams have been

*Abstract of paper by Herbert B. Reynolds, presented at the Spring Meeting of the American Society of Mechanical Engineers, Chicago, Ill., May 23 to 26, 1921.

modified so that the opening of the secondary valve is delayed. This may improve the economy to some extent near and at the best load point; however, no tests have been conducted to determine just how much improvement has been accomplished.

Fig. 3 shows the variation of steam pressure with the load at various points throughout the turbine. Tests were also conducted on the condensers and auxiliaries. The results obtained in these tests of a large power-station unit form a welcome addition to the data of tests of turbines of the same capacity installed in 1915 at the Seventy-fourth Street power station of the company, reported in a paper presented before the society in 1916, by H. G. Stott and W. S. Finlay, Jr.

McGraw-Hill Executive To Work with Hoover

Frederick M. Feiker, vice president and chairman of the editorial board of the McGraw-Hill Company, has been selected by Mr. Hoover as one of his two assistants in the Department of Commerce. Mr. Hoover has divided the bureaus of the department into two parts, one relating to navigation and fisheries, and one, which will be in charge of Mr. Feiker, relating to the Bureau of Foreign and Domestic Commerce, Standards and Census. Mr. Feiker will be in direct contact with his chief in the work of expanding these bureaus into real aids to business. He will not, however, sever his connections with the McGraw-Hill Co., having been granted a leave of absence.

F. M. FEIKER

It is Mr. Hoover's expressed intention to develop the Department of Commerce into the same relation with industry as that of the Department of Agriculture to farming. He feels that the department ought to help business in every way possible rather than simply to regulate and control it. He intends to find out what kind of data industry needs from the Government, and then to see to it that the necessary information is collected and made available. His choice of his assistant in this work is a natural one in view of Mr. Feiker's combination of a technical training, a wide view of the needs of industry and an extensive knowledge of publicity.

Mr. Feiker is an electrical engineer, having received his degree from Worcester Polytechnic Institute in 1904 at the age of 23. He did some special research work on high-potential generation and transmission immediately after graduation and then turned to publicity work with the General Electric Company. In 1906 he joined the staff of *System* magazine in Chicago, where he later established, and became managing editor of, the *Factory* magazine. In 1912 he was made chairman of the editorial board of all the A. W. Shaw publications. In 1915 he joined the McGraw-Hill organization as editor of *Electrical World*. Here, again, he saw the possibilities of a new paper, with the result that *Electrical Merchandising* was established by the company in 1916. In 1919 he was appointed editorial director of the McGraw-Hill Company, and in 1920 was elected as its vice president and chairman of the editorial board.

He has been active in the Illuminating Engineering Society and the National Electric Light Association, and as past chairman of the Editorial Conference of the New York Business Publishers Association.

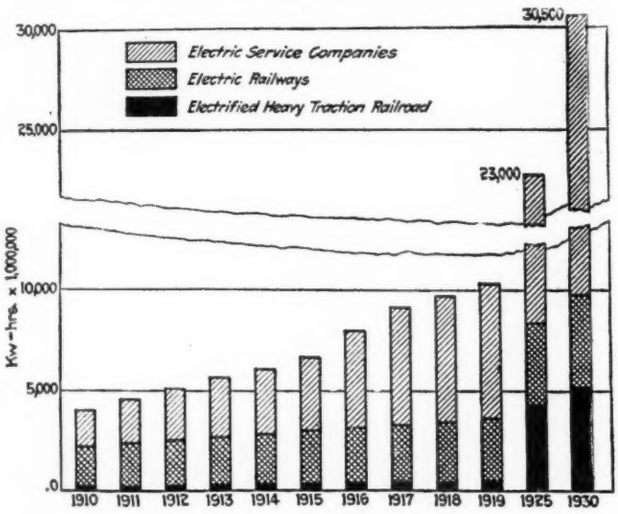
Legal and Physical Aspects of Superpower Plan

On May 13 the Superpower Survey held a meeting in New York City at which members of the advisory board and others discussed the physical, legal and financial aspects. E. C. Buckland, vice president, New York, New Haven & Hartford R.R., expressed the opinion that a charter or other legal authority will be required to harmonize the legislative and financial requirements of the superpower plan.

Essentially a charter must grant powers and limit powers. The grant of power should give the superpower corporation the right to generate and distribute throughout the Boston-Washington zone and to take by eminent domain all necessary lands or easements. On the other hand, the corporation should be limited in the purchase or sale of energy to authorized public utilities in the zone. These utilities should have the first right to subscribe for stock in proportion to their energy output.

Mr. Buckland saw no reason why Congress should not grant the power of eminent domain to the corporation which is so fundamental. This can best be obtained in one of four ways:

1. By private charter granted by Congress.
2. Under a general corporation law to be passed by Congress authorizing the incorporation of superpower corporations to operate anywhere in the United States.
3. By an amendment to the Federal Water-Power Act extending the authority of the commission to projects involving power houses generating electrical energy by water or other motive power and providing for the incorporation under a Federal charter of associations to become licensees.
4. By an amendment to the Federal Water-Power Act as above, the licensee to be a corporation organized under the law of one or more states in the Superpower Zone.



PAST AND ESTIMATED FUTURE GROWTH OF POWER REQUIREMENTS IN THE SUPERPOWER ZONE

W. S. Murray, chairman of the Superpower Survey, in his summary of the physical aspects of the Superpower Survey pointed out that an enormous coal saving could have been effected in the Superpower Zone during 1919 if the facilities which he is advocating for that district had been in existence. The savings would have amounted to 4,300,000 tons for the utilities, 9,566,000 tons for the railroads and 11,000,000 tons for the industries, or a grand total of 24,866,000 tons. If the generation of power continues unco-ordinated, he contended, the annual coal waste will be 50,000,000 tons

by 1930, which at $5.35 a ton would represent a monetary loss of $266,500,000. Through the agency of a superpower system two of the most important economies of power production can be satisfied. These would rest, first on the ability to develop hydro-electric power within the zone to maximum capacity, and, second, on the feasibility of establishing 30,000 kw. as the minimum size of generators in the Superpower Zone steam stations.

In making the survey, 315 utilities were examined, representing a capacity of 4,000,260 kw., of which 11 per cent was hydraulic and 89 per cent steam. The output of these stations was 10,301,000,000 kw.-hr., hydraulic stations producing 16 per cent of this output and steam stations 84 per cent. The steam stations consumed 11,806,000 tons of coal at a cost of $63,228,000. The average coal rate was 2.73 lb. per kilowatt-hour.

Although the maximum capacity of any steam plant in the territory was 163,000 kw. and that of any hydraulic plant 83,500 kw., the average of all steam plants was found to be 10,000 kw., while the average of hydraulic plants was 2,700 kw. An investment of $598,000,000 is represented by these plants, 85 per cent of the total being for steam plants and 15 per cent for hydraulic.

An analysis of the industries in the Superpower Zone has shown a total of 76,000 plants using 9,000,000 hp. The power requirements of these industries were further divided as shown in the accompanying table.

POWER REQUIREMENTS OF INDUSTRIES IN SUPERPOWER ZONE

Kind of Power Used	Horsepower	Approximate Percentages
Steam	5,400,000	60
Gas	300,000	3
Electric	2,800,000	31
Water	500,000	6
Total	9,000,000	100

Exclusive of Niagara Falls and St. Lawrence power, there is available within the zone for water-power development 9,000,000,000 kw.-hr. per annum. However, the utilities, railroads and industries will require 31,000,000,000 kw.-hr. annually by 1930. Allowing for economical application, probably 25 per cent of the power requirements could be supplied by hydro-electric development. To make up the remainder, it is proposed to use the high-efficiency steam plants as a base, but retain 75 per cent of the present capacity for peak-load operation. To insure the realization of the full economies of the superpower system, the future should see the installation of steam-generating equipment in units of not less than 30,000 kw.

Standardization of 60 cycle as a uniform frequency is recommended, as well as the standardization of plant and and railway equipment in so far as that may be possible.

W. S. Murray estimated that the project would require $100,000,000 each year for the next ten years, but the annual coal saving would be $266,500,000. Of the 5,000,000 kw. capacity in central stations in the zone, he believed that only 1,000,000 kw. would have to be written off in order to get the benefit of the more efficient superpower stations.

Provisions of the Coal Bills

Coal legislation is reaching a more definite stage in Washington. The Frelinghuysen seasonal coal-rate and coal-stabilization bills have been reported to the Senate. Each of these bills has come in for months of consideration by a sub-committee of the Committee on Interstate Commerce, of which Senator Frelinghuysen is the chairman. Public hearings have been held, and in addition each of the measures has received much outside attention.

The coal-stabilization bill is a compulsory fact-finding measure without regulatory provisions of any kind. The commercial part of the fact finding is to be done by the Secretary of Commerce, while the technological fact-finding authority is vested in the Bureau of Mines. The bill provides that the Secretary of Commerce, from time to time, shall investigate (1) the tonnage of coal produced and sold in commerce, including railway fuel; (2) the stocks of coal on hand in any section of the country or in such consuming territories or districts as may be outlined or designated by the Secretary and the consumption requirements in such districts; (3) the distribution of shipments in commerce, including the distribution of coal cars; (4) the contract and prevailing market prices received or paid for coal by persons engaged or interested in the mining, sale, storage or distribution of coal.

This information is to be furnished under oath by producers, wholesalers, consumers and others. Any wilful failure to furnish the figures or any false statement of fact is made punishable by a fine of not more than $1,000 or by imprisonment for not more than six months, or both. The law is not to apply to persons who consume less than 100 tons of coal annually.

Investigations as to the management, organization and practices of operating or selling concerns are eliminated from the bill as reported, and investigations of costs and profits in connection with the handling of coal can be undertaken only upon express authority from the President.

The bill directs the head of the Bureau of Mines to investigate storage, inspection, sampling, analysis, classification and economic utilization of coal. He is instructed to co-operate with dealers and consumers to encourage the construction of facilities for the storage of coal and for its utilization. He is to investigate the desirability and practicability of prescribing standards for various kinds and grades of coal and is to submit a report on the question to Congress by Dec. 5.

The Interstate Commerce Commission is instructed to co-operate in carrying out the provisions of the act and in promoting the proper distribution and use of coal cars to secure the most efficient transportation of coal and commerce.

In the seasonal rate bill the Interstate Commerce Commission is authorized to initiate, establish, approve or adjust rates to apply during specific seasons or periods, which shall be greater or less than the rates for other specified seasons or periods.

Dr. Rosa Dies Suddenly

Dr. Edward B. Rosa, for ten years chief physicist of the Bureau of Standards, died suddenly in his office in Washington on May 17. He had joined the Bureau as a physicist in 1901 and was promoted in 1910 to the position he held at the time of his death. He was responsible for building up the electrical division of the Bureau, and he had made a continual effort to make the division as valuable as possible to the industries and to the public. Probably the most notable achievement of the division is the development of the National Electrical Safety Code, which was so successful that a national system of safety codes is now being prepared along the same lines.

Dr. Rosa was born in 1861 at Rogersville, N. Y., and was educated in the public schools of Wellsville, N. Y. He attended Riverside Academy, at Wesleyan University, and was graduated from Johns Hopkins University in 1891 with the degree of Doctor of Philosophy. After his graduation he served for ten years on the faculty of Wesleyan University, leaving there finally to join the Bureau of Standards.

Bursting Pipe Kills Six

An ususually serious accident occurred recently when a tee in the steam header ruptured at the West Penn Power Co.'s plant at Connellsville, Pa. It is reported that six men lost their lives as a result of the accident.

The cause of the rupture is under investigation. It has been suggested that the trouble might have been caused by water-hammer action, but on the other hand it is claimed that the pipe of which the ruptured tee was a part had been drained prior to the accident.

In a short item in the May 17 issue, on page 801, was shown a picture of a Sterling gasoline engine driving a Lea-Courtenay pump, said to be pumping against a pressure of 350 lb. per sq.in. through a 20-in. main 4½ miles long. The fact of this very high pressure lent exceptional interest to the unit. The builders of the pump, however, now advise that it was intended for pumping against only 250 lb.

Plans of Federated American Engineering Societies

The American Engineering Council of the Federated American Engineering Societies has decided that the vacancy in the office of president caused by Mr. Hoover's recent resignation will not be filled this year. This decision was made at a recent board meeting, at which it was also determined that the next meeting of the executive board will be held in St. Louis on June 3.

It has been announced by the Federation that it will not make any further effort to secure the general reorganization of Governmental activities, but will concentrate its effort upon the establishment of a National Department of Public Works.

French and American Universities to Exchange Engineering Teachers

While the annual exchange of professors in the academic departments of American and French universities has been going on for some time, there has so far been no such exchange of teachers in engineering or applied science. Feeling that it would be to the mutual advantage of France and America to become better acquainted with each other's ideals and viewpoints in engineering, as in other subjects, the late Dr. R. C. Maclaurin, in 1919, as president of the Massachusetts Institute of Technology, consulted the presidents of six universities on or near the Atlantic seaboard, as to whether they deemed it desirable to co-operate in such a joint exchange of professors with France. Their replies being very favorable to the project, a committee composed of one member from each of the seven institutions was appointed to report on the plan and on methods of carrying it into effect. The committee met in December, 1919, and ratified the co-operative plan with some few modifications. The president of the committee is Director Russell H. Chittenden, of Yale, and its secretary, Dean J. B. Whitehead, of Johns Hopkins.

With the aid of the Institute of International Education, in New York, negotiations were undertaken between the committee and the French University Administration, with the result that the French Administration responded very cordially to the offer. The French have selected, for their first representative, Prof. J. Cavalier, rector of the University of Toulouse, and a well-known authority on metallurgical chemistry, to come to America this fall, and to divide his time during the ensuing academic year among the seven co-operating institutions—Columbia, Cornell, Harvard, Johns Hopkins, Massachusetts Institute of Technology, Pennsylvania and Yale.

The American universities have selected as their outgoing representative for the same first year (1921-22), Dr. A. E. Kennelly, professor of electrical engineering at Harvard University and the Massachusetts Institute of Technology.

It is intended that there should not only be a steady annual exchange of a professor in these various branches of applied science, but also a steady interchange of advanced students between France and America in these same fields.

A. A. E. Elects Officers

The American Association of Engineers, at its recent annual convention at Chicago, elected the following officers: President, H. O. Garman; vice president, A. N. Johnson; second vice president, A. S. Morris. Directors chosen were E. F. Ayres, Webster L. Benham, Garrison Babcock, Morris Bien, G. M. Butler and W. R. McKeen.

Mr. Garman, the new president, was for ten years on the faculty of Purdue University, and was later the leader in securing the passage of the Indiana engineer's and surveyor's license law. He is at present chief engineer and consulting engineer with the Indiana Public Utilities Commission and the Indiana Railroad Commission, having supervision of public utilities and appraisal of property.

The Niagara Falls Power Co. has increased its authorized capital stock by $8,484,000 preferred and $5,000,000 common.

New Publications

STEAM BOILER ENGINEERING (Helios). Twenty-seventh edition. Published by the Heine Safety Boiler Co., St. Louis, Mo., 1920. Cloth; 6 x 9 in.; 640 pages; 423 illustrations. Price, $1.75.

In the preface to the first edition of "Helios," published in 1903, Col. Meier wrote: "In the following pages we have some account of the fuels used in the practical arts, of the water that becomes the vehicle for transmitting their energy into mechanical power, and of the limitations imposed by their varying conditions." The truth of this statement has become more and more amplified with succeeding editions, until the latest (27th) is indeed, as its title page sets forth, a "treatise on steam boilers and the design and operation of boiler plants," and might well, with a little elaboration in certain directions, merit the old-fashioned appellation of "compendium." As a matter of fact, the present volume, with its new title, new text and new dress, is a "new edition" of the well-known "Helios" only in the sense that the small boy had the "same old jackknife" even with a new handle and new blades. There will be no fault-finding on this score, however, for the Research Department of the Heine company has produced a book which reflects credit on all concerned, and which at the merely nominal price placed upon it (barely the actual cost of printing and binding) will find a large and immediate field as a work of reference. Its sixteen chapters treat of Heine practice, boiler rating and design, superheaters, furnaces and settings, mechanical stokers, chimneys and flues, mechanical draft, piping and accessories, auxiliaries, heat insulation, heat and combustion, steam fuel, feed water, boiler testing and operation, while an index of twenty double-column pages is not the least valuable feature of the book, which covers pretty nearly everything pertaining to steam generation except other boilers than the Heine.

PULVERIZED COAL

The combustion Engineering Corporation, 43 Broad St., New York City, has prepared two interesting pamphlets, "Use of Pulverized Coal Under Central Station Boilers" and "Powdered Coal Application to Four 2,640-hp. Boilers" which it is distributing free of charge. The first of these comprises the report of John Anderson, chief engineer of power plants of the Milwaukee Electric Ry. and Light Co., describing a test at the Oneida St. plant of the company which was one of the first large public utility plants to use powdered coal. The other pamphlet contains a copy of a speech before the Engineers' Society of Western Pennsylvania on the pulverized coal installation at the River Rouge plant of the Ford Motor Co.

Personals

N. A. Lee has been made superintendent of the municipal electric light plant and water-works systems of Luverne, Minn.

William L. Rockwell has resumed his practice as hydraulic consulting engineer at Austin, Tex., after completing a two years' stay in the West Indies.

Homer J. Forsythe has resigned as manager of the construction division of the engineering department of the du Pont company to take a position as assistant general manager of the Hyatt Roller Bearing Co., of Newark, N. J.

R. W. Callaway has resigned as superintendent of the Municipal Gas, Water and Light Plants of Clay Center, Kan., to take the same position in Augusta, Kan. He has rebuilt the plants at Clay Center, and also at Newkirk, Okla., where he was formerly superintendent for three years.

H. A. Von Schon, consultant in hydroelectric engineering, public utility valuations, underwriters reports, etc., has been appointed by the court commissioner to regulate water-power operations on the St. Joseph River, with his office at South Bend, Ind. He is to continue his consulting practice.

Henry R. Towne has been made honorary member of the A. S. M. E. Mr. Towne has been a member since 1882, was vice president in 1884 and president in 1889, and is head of the Yale & Towne Manufacturing Co.

Society Affairs

The A. S. M. E. Regional Meeting planned for June 13-14 at Cleveland has been postponed to October.

The American Society of Mechanical Engineers is already planning for its 1922 spring meeting, and has announced Atlanta, Georgia, as the meeting place.

The Stoker Manufacturers' Association has changed the date of its annual convention from May 24-26 to June 14-16, at the Red Lion Inn, Stockbridge, Mass.

The Engineering Society of Western Massachusetts will hold its second annual meeting at the Hotel Kimball, Springfield, Mass., May 25 at 6:30 p.m.

The American Society for Testing Materials will hold its 24th annual meeting June 20-24 at the New Monterey Hotel, Asbury Park, N. J. The secretary is C. L. Warwick, 1315 Spruce St., Philadelphia, Pa.

Trade Catalogs

The Pennsylvania Pump and Compressor Co., Easton, Pa., has issued a new bulletin describing its line of air compressors and dry vacuum pumps.

The Combustion Engineering Co., 43 Broad St., New York City, is sending out a 6 x 9-in. 30-page revised catalog describing the Coxe Stoker and illustrating its use.

The Yarnall-Waring Co., Chestnut Hill, Philadelphia, is distributing a bulletin (R-1401) explaining its new balanced control valve, which is made in angle and globe patterns and was designed primarily for use with the company's "V-Notch" recording meter.

FUEL PRICES

BITUMINOUS COAL

The following table shows the trend of the spot steam market in various coals (mine-run basis, f.o.b mines):

Coal	Market Quoted	May 10 1921	May 17 1921
Pocahontas,	Columbus	$3.50	$3.50@3.75
Clearfield,	Boston	2.35	2.00@2.85
Somerset,	Boston	2.95	2.25@3.50
Pittsburgh,	Pittsburgh	2.10	2.00@2.20
Kanawha,	Columbus	2.25	2.25@2.35
Hocking,	Columbus	2.20	2.10@2.25
Pittsburgh No.8	Cleveland	2.20	2.25@2.30
Franklin, Ill.,	Chicago	3.40	3.00@3.50
Central, Ill.,	Chicago	2.95	2.25@3.00
Ind. 4th vein,	Chicago	3.40	2.75@3.50
Standard,	St. Louis	1.90	1.90
West Ky.,	Louisville	2.00	2.00
Big Seam,	Birmingham	2.95	2.85@3.10
S. E. Ky.,	Louisville	2.60	2.50@2.75

DIESEL FUEL OIL

New York—On May 19, Port Arthur light oil, 23@25 deg. Baumé, 5¼c. per gal. 30@35 deg., 6½c. per gal. f.o.b. Bayonne, N. J.

Chicago—May 7, for 24@28 deg. Baumé, 60@70c. per bbl.; 32@34 deg., 2¼@2½c. per gal. In tank cars f.o.b. Oklahoma refinery, or freight adjusted.

St. Louis—May 14, prices f.o.b. cars, tank lots: 24@26 deg. Baumé, 65c. per bbl.; 26@28 deg., 75c.; 28@30 deg., 85c.; 32@34 deg., 2½c. per gal.

Baltimore—On April 23 f.o.b. refinery; in tank-car lots; 24+ deg. Baumé, 6¼c.; 26@28 deg., 6½c.; 30@34 deg., 7⅜c.; 14+ deg., $1.95 per bbl.; 16@20 deg., $1.85 per bbl.

Pittsburgh—On May 2, f.o.b. refinery; Pennsylvania, 36@40 deg., 5c. per gal.; Oklahoma, 24@30 deg., 65c. 32@34 deg., 75c. per bbl.; gas oil, 32@34 deg., 2½c. per bbl., 36@38 deg., 2⅜c. 38@40 deg. 3c.

Philadelphia—On April 12; 26@28 deg. Baumé, Oklahoma, 85c. per bbl.; 30@34 deg., Oklahoma (group 3), 3c. per gal.; 16@20 deg., Seaboard, 5c. per gal.

Cincinnati—April 23, for 22@28 deg. Baumé, 7.34c. per gal.

Cleveland—April 23, for 22@28 deg. Baumé, 5½c. per gal.

New Construction

PROPOSED WORK

Mass., Chelsea—The Bureau of Yards & Docks, Navy Dept., Wash., D. C., will soon receive bids for installing two new gasoline storage tanks and one new pump at the Naval hospital here.

Mass., New Bedford—The School Comn. is having plans prepared for a 3 story, 149 x 161 ft. junior high school on County St. About $600,000. F. I. Cooper Corp., 33 Cornhill St., Boston, Archt. R. D. Kimball Co., 6 Beacon St., Boston, Mechanical Engr.

Mass., New Bedford—Wamsutta Mills, Wamsutta St., wll soon award the contract for a 1 story, 50 x 60 ft. boiler house addition. C. T. Main, 201 Devonshire St., Boston, Archt and Engr.

Mass., Wakefield—The High School Bldg. Comn. had plans prepared for a 3 story, 208 x 250 ft. high school, assembly hall and gymnasium including a steam heating system on Main St. About $500,000. F. I. Cooper Corp., 33 Cornhill St., Boston, Archt. R. D. Kimball Co., 6 Beacon St., Boston, Mechanical Engr.

Conn., Hartford—The Masonic Hall Association, 51 Ann St., plans to build a 12 story masonic temple. About $1,000,000. Architect not yet selected.

Conn., Stratford (Bridgeport P. O.)—The High School Bldg. Comn. had plans prepared for a 2 story, 245 x 266 ft. high school assembly hall and gymnasium including a steam heating system on North Parade St. About $700,000. F. I. Cooper Corp., 33 Cornhill St., Boston, Mass., Archt. and Engr.

N. Y., Buffalo—The Elliott Club, Ellicott Sq. Bldg., plans to build a 9 story clubhouse on Niagara Sq. About $2,000,000. Architect not yet selected.

N. Y., Buffalo—Organized Labor, 383-389 Ellicott St., is having plans prepared for a 10 story, 71 x 150 office and hall on Ellicott St. About $300,000. Esenwein & Johnson, Ellicott Sq. Bldg., Archts.

New York (Bronx Boro.)—The Dept. of Health, 505 Pearl St., New York City, will receive bids until May 26 for furnishing labor and material for installing one additional boiler and relocating one present boiler in the power house at North Brothers Island.

N. Y., New York (Brooklyn Boro)—The Bd. Educ., 500 Park Ave., New York City, will soon award the contract for a school on Sanford St. About $800,000. C. B. J. Snyder, Municipal Bldg., New York City, Archt. and Engr.

N. Y., New York (Manhattan Boro)—The All American Cable Inc. is having plans prepared for altering an 8 story office building on Broad St. between Stone and South Williams Sts. About $300,000. Warren & Wetmore, 10 East 47th St., Archts. and Engrs.

N. Y., New York (Manhattan Boro)—The Bank of America, Madison Ave. and 40th St., is having plans prepared for a 23 story, 81 x 195 ft. bank and office building at 41-45 Pine St. About $2,500,000. Trowbridge & Livingston, 537 5th Ave., Archts. and Engrs.

N. Y., New York (Manhattan Boro)—The J. J. Finnerty Constr. & Holding Co., 1193 3d Ave., is having plans prepared for a 2 story theater, office and store building on Lenox Ave. and 142d St. About $250,000. G. M. McCabe, 96 5th Ave., Archt. and Engr.

N. Y., New York (Manhattan Boro.)—The Mardel Estates Inc., 125 Bway, is having plans prepared for a 6 story, 87 x 137 ft. apartment house at 645 West 162d St. About $300,000. Springsteen & Goldhammer, 32 Union Sq., Archts. and Engrs.

N. Y., New York (Manhattan Boro)—The United States Mortgage & Trust Co., Madison Ave., will soon award the contract for a 2 story bank building on Madison Ave. and 74th St. About $500,000. H. Otis Chapman, 334 5th Ave., Archt. and Engr.

N. Y., Syracuse—The Hotel Syracuse Corp., c/o Olmsted, Van Bergen & Searle, plans to build a 12 story hotel on South Warren, Harrison and East Onondaga Sts. About $5,000,000. Architect not yet selected.

N. J., Atlantic City—W. G. Souders & Co., 208 South La Salle St., Chicago, has had preliminary plans prepared for a 12 story, 335 x 350 ft. apartment hotel including a high pressure steam heating system on Albany Ave., here. About $5,000,000. R. S. DeGolyer, 7 South Dearborn St., Chicago, Archt.

N. J., Bridgeton—The Bd. Educ. plans to build a 2 story high school. About $250,000. H. A. Hill, 406 State St., Trenton, Archt

N. J., Florence—Florence Twp. plans an election to vote on $130,000 bonds to build a pumping station with 2 large gasoline driven pumps direct connection, etc. C. D. Green, Engr.

N. J., Jersey City—The Claremont Bank, c/o Mowbray & Uffinger, Archts. and Engrs., 56 Liberty St., New York City, will soon award the contract for a 1 story bank and office building. About $500,000.

N. J., Montclair—E. Hincke will soon award the contract for a 2 story, 222 x 284 ft. theater including an indirect steam heating system and Kewanee boilers, on Bloomfield and Church Sts. About $900,000. W. E. Lehman, 738 Broad St., Newark, Archt. and Engr.

N. J., Orange—A. Richter, Main St., East Orange, will soon award the contract for a 2 story theater including an indirect steam heating system and Kewanee boilers on Main and Center Sts. About $300,000. W. E. Lehman, 738 Broad St, Newark, Archt. and Engr.

Pa., Dormont (Pittsburgh P. O.)—The Bd. Educ. will soon award the contract for a 2 story high school and 38 x 68 ft. boiler house on Annapolis Ave. Cost between $400,000 and $500,000. P. C. Dowler, Magee Bldg., Pittsburgh, Pa., Archt.

Pa., Philadelphia—The Amer. Stores Co., York and Noble Sts., is in the market for an 80 hp. engine for its Victor bakery No. 2.

Pa., Philadelphia—The Rainbow Dye Wks., Howard and Lehigh Aves., will be in the market later for two return tubular boilers.

Pa., Staunton—J. A. Wetmore, Supervising Archt., Treasury Dept., Wash., D. C., will receive bids until June 15 for a heating boiler, etc., in the United States Post Office, here.

Md., Annapolis—The Bureau of Yards & Docks, Navy Dept., Wash., D. C., will receive bids until June 1 for radio towers, here.

Va., Alexandria—The Herfurth Engine & Machinery Co., Duke St., is in the market for two 150 hp. return flue type boilers good for 125 lbs. pressure. (Used.) R. W. Herfurth, Purch. Agt.

W. Va., Charleston—J. W. Solof, 1584 Quarrier St., plans to build a 4 story hotel on Quarrier St. About $250,000.

W. Va., Huntington—A. F. Jones, c/o Lakewood Hospital, 14519 Detroit Ave., plans to build a 12 story hospital. About $1,000,000.

Fla., Lakeland—The Polk County School Bd., Bartow, plans to install a heating plant in the Lake Morton School, here. About $15,000. F. H. Trimble, Orlando, Archt.

Fla., Quincy—The city plans to vote $75,000 bonds to construct a hydro-electric plant along the Little River, here.

Fla., St. Petersburg—The City Comn. will receive bids until June 6 for four 1,000 gal. centrifugal pumps with 80 hp. motor, two air compressors, one 1,500 gal. centrifugal pump with gas engine for emergency. About $80 000 R. E. Ludwig, City Hall, Engr. Noted May 10.

O., Ashtabula—The Silurium Mfg. Co., Sloan Bldg., Cleveland, plans to build a 1 story factory. About $500,000. E. Steinbrenner, Pres. Architect not yet selected.

O., Cleveland—The city will receive bids until May 26 for installing a heating and ventilating system in the city hospital buildings. About $200,000. J. H. MacDowell, City Hall, Archt.

O., Cleveland—The Knoble Refining Co., c/o L. A. Ritzman, 607 Canal Rd., will soon award the contract for a 1 story factory and boiler house on East 99th St. and Elk Ave. About $80,000. L. C. Scott, Archt.

O., Cleveland—The State Banking & Trust Co., East 55th St. and Bway., plans to build a 4 story commercial building. About $500,000. C. J. Hodous, Secy. Architect not yet selected.

O., Conneaut—The Bd. Educ. wll receive bids until May 26 for a 2 story, 260 x 333 ft. junior high school on Sandusky and Adams Sts. Cost between $500,000 and $600,000. Bartholomew, McCullough & Smith, Ferguson Bldg., Pttsburgh, Pa., Archts.

O., Madison—The Lyon King Implement Co. is in the market for motors, etc. W. E. Arnold, Pres.

Ind., Indianapolis—The James Whitcomb Riley Memorial Hospital Association plans to build a memorial hospital on West Michigan St. About $500,000. R. F. Daggett, 962 Lenicke Annex, Archt.

Ind., South Bend—The Oliver Hotel Corp., 105 North Main St., is having plans prepared for a 7 story, 65 x 125 ft. hotel addition including an extension to the present steam heating system on Washington and Main Sts. About $600,000. H. H. Green, 30 North Michigan Ave., Chicago, Ill., Archt.

Mich., Detroit—The Bd. of Water Comrs. will soon award the contract for furnishing labor and material for the construction of a 1 story, 57 x 220 ft. superstructure for low lift pumping station at the Water Works Park here. About $100,000. T. A. Leisen, Water Works Park, Engr.

Mich., St. Clair—The Bd. Educ. will soon award the contract for a 2 story, 85 x 140 ft. high school including a steam heating system. About $325,000. Perkins Fellows & Hamilton, 814 Tower Court, Chicago, Ill., Archts.

Ill., Aurora—The Durabilt Steel Locker Co., 65 South Bway., is in the market for one 20 hp., 3 phase, 220 volt, 60 cycle, a.c. induction motor. (Used.)

Ill., Chicago—S. Scott Joy, 2001 West 39th St., is having plans prepared for a 3 story, 150 x 170 ft. apartment house including a steam heating system. About $300,000.

Ill., Chicago—G. A. Nilson, 155 North Clark St., is having plans prepared for an 11 story, 175 x 200 ft. apartment hotel including a steam heating system on Sheridan Rd. and Foster Ave. About $1,500,000. J. A. Nyden, 190 North State St., Archt.

Ill., Chicago—Anton Will, c/o Paul F. Olsen, Archt., 127 North Dearborn St., will soon award the contract for a 3 story, 140 x 170 ft apartment house including a steam heating system on Lake Terrace. About $700,000.

Ill., Joliet—The Franciscan Fathers of the Sacred Heart Province, c/o St. Peter's Church, Clark and Polk Sts., Chicago, plans to build a 3 story preparatory seminary including a steam heating system. About $800,000. Address Rev. Samuel Macke. Architect not yet selected.

Ill., Kankakee—J. A. Wetmore, Supervising Archt., Treasury Dept., Wash., D. C., will receive bids until June 15 for heating boiler, etc., in the United States Post Office here.

Ill., Oak Park—The Oak Park Hotel Co., c/o Henry Raeder, Archt., 20 West Jackson Blvd., is having plans prepared for an 8 story, 150 x 170 ft. hotel including a steam heating system on Erie St. and Oak Park Ave. About $1,500,000.

Ill., Wheaton—Wheaton College plans to build a number of various size buildings including a steam heating system. About $2,000,000. C. H. Blanchard, Pres.

Wis., Cedarburg—The E. & W. Mfg. Co., 325 Oregon St., Milwaukee, is in the market for power machinery for its factory here.

Wis., Milwaukee—Cahill & Douglas, Engrs., 217 West Water St., will soon award the contract for one 150 hp. boiler, for the C. Abresch Co., 399 4th St.

Wis., Milwaukee—The Sewerage Comn. will receive bids until June 3 for the foundation of a 97 x 204 ft. main power house on Jones Island. Cost between $50,000 and $60,000. T. C. Hatton, City Hall, Engr. Noted Oct. 12.

Wis., Sauk City—The village will receive bids until May 26 for a new water-works system including pumps, pressure tank and air compressor. P. J. R. Post, Clk. H. E. French, Baraboo, Engr.

Wis., Sheboygan—The Security Natl. Bank will soon receive bids for a 7 story, 80 x 110 ft. bank and office building. Cost between $600,000 and $700,000. Brost & Philipp, 405 Bway., Milwaukee, Archts.

Ia., Waterloo—J. A. Wetmore, Supervising Archt., Treasury Dept., Wash., D. C., will receive bids until June 15 for a heating boiler, etc., in the United States Post Office here.

Kan., Emporia—The Citizen Natl. Bank is having plans prepared for a 7 story, 62 x 120 ft. bank and office building including a steam heating system. About $350,000. Weary & Alford, 1732 South Michigan Ave., Chicago, Ill., Archts.

Kan., Horton—I. Griffith, City Clk., will receive bids until May 31 for one Diesel engine and generator for the water and light plant here.

Neb., Pawnee City—The city is having plans prepared for an addition to the lighting plant. About $85,000. E. T. Archer & Co., Kansas City, Mo., Engrs. The city contemplates pruchasing two new engines and two new boilers.

S. D., Redfield—The city will receive bids until June 9 for 3 centrifugal pumps each 1,000 gal. per min. capacity, 1 centrifugal pump of 500 gal. per min. capacity, 1 steam turbine and 3 electric motors for direct connection to centrifugal pumps, 1 fire pump, motor driven, and a 150,000 gal. tank on 90 ft. tower. About $30,000. Cory & LeCorq, Aberdeen, Engrs.

S. D., Sioux Falls—The Bd. Educ. will soon award the contract for a 2 story, 218 x 288 ft. high school including a steam heating system on 11th St. between Dakota and Minnesota Aves. About $900,000. A. Ayres, Pres. Perkins & McWayne, Paulton Blk., Archts.

N. D., Fessenden—The city plans to build a water tower and pump station. About $30,000.

Mo., Fulton—The city will receive bids until May 28 for a new unit to electric light plant. About $25,000. Address F. T. Kaker.

Mo., St. Louis—The Ancient Arabic Order, Nobles of the Mystic Shrine, plans to build a 4 story, 370 x 380 ft. hospital including a steam heating system on Kingshighway and Clayton St. About $1,000,000. W. B. Ittner, Bd. Educ. Bldg., Archt.

Mo., St. Louis—P. J. Bradshaw, Archt., International Life Bldg., will soon award the contract for a 12 story apartment hotel including a steam heating system on Grand and Lindell Sts., for the Thirty Sixth St. Realty Co., 111 North 7th St.

Mo., St. Louis—The Jewish Hospital Bd., 5415 Delmar St., is having plans prepared for a hospital including a steam heating system on Kingshighway and Forrest Park. About $1,500,000. Graham, Anderson, Probst & White, 80 East Jackson Blvd., Chicago, Ill., Archts.

Tex., Point Isabel—The Bureau of Yards & Docks, Navy Dept., Wash., D. C., will soon receive bids for furnishing and installing a motor driven centrifugal pump and constructing a pump house, etc., here.

Okla., Duncan—The city voted $300,000 bonds to construct an 800 kw. electric light plant, distributing system and white way. Benham & Mullergren, Firestone Bldg., Kansas City, Mo., Engrs. Noted April 26.

Utah, Salt Lake City—The city will receive bids about June 5 for a 3 story, 86 x 430 ft. high school on 2d West St. About $800,000. Canon & Fetzer, Templeton Blvd., Archts. and Engrs.

Cal., Los Angeles—F. Meline, Archt., representing company, 6779 Hollywood Blvd., is preparing plans for a 7 story apartment house including a steam heating and cold storage system and refrigeration plant, on Wilshire Blvd. and Catalina St. About $850,000

Cal., Los Angeles—The Phillips-Walker Syndicate, c/o Morgan, Walls & Morgan, Archts., 1124 Van Nuys Bldg, will soon award the contract for a 12 story, 120 x 155 ft. hotel including a steam heating system on Olive St. between 6th and 7th Sts.

Cal., Pasadena—The Pasadena Hospital Association, Congress Ave., is having plans prepared for a 4 story, 47 x 261 ft. hospital building and a 2 story, 38 x 60 ft. power house on Congress St. near Pasadena Ave. A steam heating and refrigeration system will be installed in same. Myson Hunt, 1107 Hibernian Bldg., Archt.

Ont., Exeter—The Ontario Flax Mills is in the market for $15,000 worth of new equipment including boiler, engine and flax machinery. L. Davis, Mgr.

Que., Montreal—The Eng. Equipment Co., New Birks Bldg., Cathcart St., is in the market for one 12 x 12 belt driven 100 lb. air compressor. (Good condition and guaranteed—second hand.)

Ont., Goderich—The Natl. Shipbuilding Co. plans to rebuild part of its plant including boiler shop on Maitland St., which was destroyed by fire. About $125,000.

Ont., Toronto—The Belle Ewart Ice Co., 156 Yonge St., plans to build an artificial ice plant on Parliament St. Ice manufacturing machinery will be installed in same. About $25,000.

Que., Verdun—The city, City Hall, will receive bids until June 1 for extensions to the filtration plant and additional panels to electric switch-board. About $100,000. C. E. Gyhsons, Engr.

Ont., Walkerville—The School Bd., 83 Devonshire Rd., is receiving competitive plans for a high school. About $300,000. W. Thorburn, Secy.

Ont., Windsor—W. B. Winter and A. A. Little, 35 Elm Ave., will receive bids until June 4 for a 2 story, 50 x 200 ft. market building including a refrigerating plant and equipment on Quellette Ave. About $150,000.

Man., Brandon—The Imperial Oil Ltd. plans to build a 50 x 200 ft. marketing plant including a boiler house, warehouse, garage, etc. About $250,000. W. S. L. Paterson, Mgr.

T. H., Pearl Harbor—The Bureau of Yards & Docks, Navy Dept., Wash., D. C., received bids for the installation of an electrical distributing system at the Naval Air Station, here, from Butte Electric Equipment Co., 530 Folsom St., San Francisco, Cal., $82,576; Teves Joaquin, 1193 Fourth St., Honolulu, T. H., $85,361; Mack & Mack, 103 Park Ave., New York City, $87,682.

CONTRACTS AWARDED

Conn., Bridgeport—The Crane Co., South Ave., has awarded the contract for remodeling and enlarging the boiler house, to the T. V. Pardy Constr Co., 1481 Seaview Ave. About $125,000.

N. Y., Long Island City—The Felrose Constr. Co., c/o Gronenberg & Leuchtag, Archts. and Engrs., 303 5th Ave., New York City, will build five 5 story, 100 x 130 ft. apartment houses on 5th Ave. near Jamaica Ave. Work will be done by day labor.

N. Y., New York (Manhattan Boro)—The New York Edison Co., 130 East 15th St., has awarded the contract for a sub-station on 40th St. and 1st Ave., to Levering & Garrigues, 552 West 23rd St., for a sub-station on Cedar St., to Frank M. Madden Co., Inc., 1369 Bway., at $130,000, and for a sub-station on Greene St., to the Kenwell Contg. Co., 841 Bway., at $60,000. Noted May 17.

N. Y., New York (Manhattan Boro)—J. Paterno & Son, 239 West 72nd St., will build a 13 story, 60 x 100 ft. apartment house at 911-915 West End Ave. Work will be done by day labor.

N. Y., New York (Manhattan Boro)—The 22 West 77th St. Inc., 299 Madison Ave., has awarded the contract for a 6 story, 56 x 90 ft. apartment house, to Fred F. French Co., 299 Madison Ave. About $300,000.

N. Y., Utica—The Utica Gas & Electric Co., 222 Genesee St., will build a power house. About $1,750,000. Work will be let by separate contracts. Noted March 1.

Tenn., Paris—The Louisville & Nashville Ry. has awarded the contract for a 125 x 150 ft. boiler house here, to G. H. Rommel Co., 958 Logan St., Louisville, Ky. About $100,000.

Wis., Sheboygan Falls—The Falls Roller Mills, c/o E. Gonzerbach, Mgr., will build a 5 story, 80 x 140 ft. flour mill including power machinery, on Main St. About $75,000. Work will be done by day labor.

Minn., Buffalo—The city has awarded the contract for one deep well, motor driven pump to have a 250 gal. per min. capacity, etc., to J. W. Hildred Co., 1019 Commerce Bldg., St. Paul, at $3,000.

Minn., Minneapolis—The Bd. Educ. has awarded the contract for installing a heating and ventilating system in the 3 story, 200 x 300 ft. high school on 28th Ave. South and East 41st St., to H. Kelly & Co., 925 Plymouth Bldg., at $84,081. Noted May 10.

Minn., Minneapolis—The Church of the Ascension, c/o Rev. J. Harrington, 1725 Bryant Ave., North, has awarded the contract for a 2 story, 77 x 154 ft. community building including a central heating plant, etc., on Bryant Ave. North and 18th St., to J. and W. A. Elliot Co., 906 Lumber Exch. Bldg., at $150,000.

Mo., St. Joseph—Morris & Co., South St., has awarded the contract for boilers, to the Natl. Industrial Boiler Co., Nashville, Tenn. About $19,916.

Wyo., Laramie—The Bd. of Trustees has awarded the contract for a 3 story heating plant including two 300 hp. boilers, etc., for the State University, to Archie Allison, Cheyenne. About $90,000. Noted March 29.

Ore., Portland—The city has awarded the contract for a dam, settling basin, screen house and a 17 x 25 ft. power house at the Headworks of the City Water Dept. along the Bull Run River, here, to the Hauser Constr. Co., 507 Henry Bldg., at $220,000.

Ont., London—The Bd. Educ. has awarded the general contract for a 2 story, 180 x 320 ft. school, to the Kingston Constr. Co. Ltd., at $308,000. A steam heating system will be installed in same.

Ont., Windsor—The Border Cities Hotel Co. has awarded the contract for a 10 story, 90 x 175 ft. hotel including a steam heating and ventilating system on Quelette Ave., to P. H. Secord & Sons, 133 Nelson St., Brantford. About $1,750,000.